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TRANSACTIONS

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NEW YORK, March 27, 1903.

The 174th meeting was held this date at 12 West 31st Street.

President Charles F. Scott called the meeting to order at 8:20 P.M. and said that the Secretary had an announcement to make.

SECRETARY POPE:—At the meeting of the Board of Directors this afternoon, the following 200 Associates were elected:

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Total, 200.

And the following Associates were transferred to the grade of Member:

Recommended by Board of Examiners, February 6, 1903.

B. V. SWENSON, Assistant Professor of Electrical Engineering, University of Wisconsin, Madison, Wis.

JAMES SWINBURNE, Consulting Engineer, London, England.

At the meeting of the Board of Directors this afternoon, after the canvass of the nominations, the following ticket was formulated: For President, B. J. Arnold, of Chicago. C. O. Mailloux was also nominated, but his nomination was withdrawn at his personal request. The nominations for Vice-Presidents are: Calvin W. Rice; W. S. Barstow; Ralph D. Mershon. For Managers: Dr. Samuel Sheldon; W. C. L. Eglin; George F. Sever; A. H. Armstrong; For Treasurer, George A. Hamilton. For Secretary, Ralph W. Pope.

HIGH TENSION TRANSMISSION LINES.

INTRODUCTION BY PRESIDENT SCOTT.

The invention of the steam engine underlies the progress of the nineteenth century. Cheap and abundant mechanical power has been a prime factor in that advancement. The railroad, the steamship, the machine shop, the factory, the rolling mill, the modern printing press and the mine hoist are developments which are based upon the steam engine. If the coal supply be shut off, the whole mechanism of our modern civilization comes to a standstill. There have been two lines of development, one of the engine for producing power; the other of machines and appliances for utilizing power. On the one hand, the development has been toward engines of large output to secure highest efficiency, and on the other hand, its load of innumerable tools and machines has sprung up demanding power often in small units and sometimes at varying speed. The development of the engine and of the machines for utilizing power has been much more rapid than that of the appliances for transmitting and distributing power from the source to the consumption. All of the various agencies, shafting, belting and various types of mechanical, pneumatic and hydraulic transmission—the primitive methods of transmission—found their ready limitations in efficiency, in capacity or in distance. It was because it supplied this missing link so effectively that the electric motor and electric power distribution has had so phenomenal a development. Electric distribution is so far superior in point of flexibility, efficiency and effectiveness to other methods that it has superseded them except in the most limited fields. But the transcendent characteristic of electric transmission is its application to long dis-

tances. Compared with preceding methods of transmission, electric distances are infinite.

Electric transmission in its unique and infinitesimal form has replaced the speaking tube by the telephone, and has given new possibilities to human speech. So, also, it has given to power development—the vital element in the industrial and commercial progress of the past century—possibilities of a new order. It not only transmits and conveys, but it has made available a new source of power—not beds of stored energy, but waterfalls of wasting energy.

The relation between distance and voltage is well known. The past ten or a dozen years have witnessed a steady advance in the voltages in commercial use. Additions from the experimental and undeveloped regions of high voltage have been conquered and brought into the domain of commercial service. The line between that which is practicable, and that which is indefinite and uncertain, has continually advanced. Each increase in voltage introduces new problems, reveals new classes of phenomena and presents difficulties more complex. Problems in construction and design and installation of apparatus, problems in insulators and line construction, problems in switching, controlling and measuring current, problems in lightning and static protection have been presented and solved with each advance in voltage. It has not been so many years since 100 or 200 k.w. to be transmitted 20 or 30 miles at 10,000 volts, was considered a somewhat remarkable undertaking.

The changes from the conditions of ten years ago to those of to-day have been, step by step, along the lines of scientific and engineering progress. The advance has been an evolution. The problems in transmission have been engineering problems, they have been far-reaching problems. Electrical theory, mathematical formulæ, the brilliant inventor, the skillful designer, the careful experimenter and the intelligent operator have all contributed to the continuous solution. Prime factors in the advance have been experience, and the ability to interpret experience and make it the foundation for further advance. The purpose of the Transmission Committee of THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS is to utilize experience. Mistakes have been made; they have been overcome. Experience has demonstrated what is successful. There is no credit to the electrical engineering profession in reducing the efficiency of electrical enterprises by repeating mistakes. The responsibilities

which rest upon the profession call for the most efficient coöperation for the elimination of inadequate methods. We must crystallize through present practice that which should be made standard practice. We must make definite the steps already taken and lay the foundation for the future.

The progress in high tension transmission is indicated by the transformer statistics of one of the large manufacturing companies. Transformers for 10,000 volts and over have been built during the past twelve years. Units recently built have three times the output of the largest transformers of five years ago. The aggregate output has been over a million kilowatts. The average kilowatt output per month during the past year is equal to the total output during the first seven years. The output of the past two years has exceeded that of the preceding ten years.

I repeat that the transmission problem is an engineering problem. It is not a simple one. It is difficult; it is comprehensive; it is not a one man problem to be solved by some individual with a peculiar scheme. It is a problem for the engineering profession. It is one to which the engineers who operate plants, who use apparatus as well as those who invent and design must contribute. We must coöperate. After we have helped one another all we can there are still problems which will tax the most able and most active.

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*A paper read at the 174th Meeting of
the American Institute of Electrical Engi-
neers, New York, March 27, 1903.*

MECHANICAL SPECIFICATIONS OF A PROPOSED STANDARD INSULATOR PIN.

BY RALPH D. MERSHON.

A mathematical consideration of the fibre stresses in wooden insulator pins and a recommendation as regards standard dimensions and methods of construction.

At present no general standard exists in the matter of Insulator Pins. As a result, there is often confusion and dissatisfaction in ordering and obtaining pins. This discussion of a proposed standard pin is intended to lead up to a general specification covering wooden pins, and, so far as it may, metal ones.

Theory.—The expression for the extreme fibre stress at any point of a beam of circular section fixed at one end and loaded at the other, as in Fig. 1 is

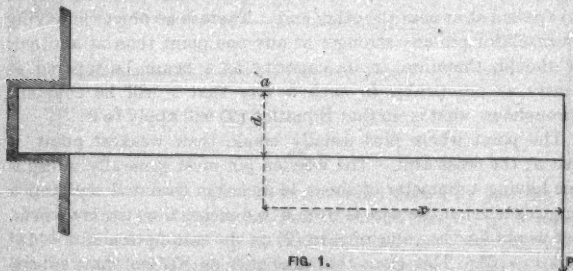


FIG. 1.

$$s = \frac{P x}{.0982 d^3} \quad (1)$$

where (assuming inches and pounds as our units) P is the pull or weight in pounds; x is the distance in inches from the point of application of P to any point a of the beam; d is the diameter in inches at the point a ; s is the extreme fibre stress in pounds per square inch, *i.e.*, s is the stress on the extreme fibres at the top and bottom of the beam at the point a .

This equation shows that for a given pull P the fibre stress at any point a at a distance x from the point of application of P varies directly as x and inversely as the cube of d . It is possible, therefore, to design a beam of circular section whose diameter in passing from the point of application of P to the point of support shall vary in such a way that s will have the same value all the way along the beam. Such a beam will be of uniform strength throughout its length. The value which, in such a beam, d must have at any point distant x from the outer end may be found by assuming s and P constant in Equation (1) and solving for d in terms of x . This gives

$$d = \left(\frac{P}{.0982 s} \right)^{\frac{1}{3}} x^{\frac{1}{3}} = K x^{\frac{1}{3}} \quad (2)$$

where K is a constant whose value must be determined from the extreme fibre stress allowable with a given pull P . Equation (2) shows that in order to have the beam of uniform strength throughout its length, its diameter must vary as the cube root of the distance from the point of application of its load.

An insulator pin is the case of a beam of circular section fixed at one end and with a load (any side pull which may come upon it) applied at or near the other end. There is no object in having an insulator pin any stronger at any one point than at another. It should, therefore, in its capacity as a beam, be tapered as nearly as practicable in such a way that s will be constant throughout; that is, so that Equation (2) will apply to it.

The point where pins usually break, their weakest point, is just at the cross arm. The wooden pin most generally in use is one having a diameter of about $1\frac{1}{4}$ inches in the cross arm and a length such that the wire is from 5 to 6 inches from the cross arm. Let us obtain the value of K in (2) on the assumption of $d = 1\frac{1}{4}$ and $x = 5$. This gives the value of K as .877, so that, substituting, (2) becomes

$$d = .877 x^{\frac{1}{3}} \quad (3)$$

From (3) we may find the diameter required at any point in any length of pin, the pin to be of uniform strength throughout. Substituting various value of x we have the following:

x (inches)	d (inches)
1	.877
2	1.106
3	1.263
4	1.395
5	1.5
6	1.592
7	1.678
8	1.754
9	1.825
10	1.888
11	1.95
13	2.06
15	2.17
17	2.25
19	2.34
21	2.42

This table shows that for a pin having upon it a pull one inch above the cross arm, the diameter at the cross arm must be .877 inches; that one having a pull upon it 10 inches above the cross arm must have a diameter at the cross arm of 1.88 inches, etc.

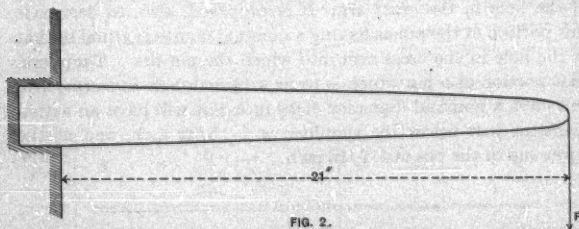


FIG. 2.

Fig. 2 is a sketch of such a theoretical pin drawn by plating the above values to a scale one-quarter of full size. Fig. 2 represents all sizes of pins up to and including one, the pull upon which is applied 21 inches above the cross arm. That is, if we want a theoretical 6 inch pin we must cut 6 inches off the end of Fig. 2 and use that; for a 10 inch pin we must cut off 10 inches, etc.

The practical pin must be a modification of the theoretical pin. The end must be square and a portion of the small end must be threaded. The pin must also have a shoulder just above the cross arm. It will be noticed that, except near the end, the sides of the theoretical pin are practically straight. It will suffice, therefore, if in designing a pin we fix the diameter at the lower end of the thread portion and the diameter just above the cross arm and make the contour between these points a straight line.

Threaded End.—It is proposed to make the diameter of the small end of the pin 1 inch; the length of the threaded portion $2\frac{1}{2}$ inches; and the diameter at the lower end of the threaded portion 1.25 inches, so that the threaded portion will taper from 1.25 inches to 1 inch in a length of $2\frac{1}{2}$ inches. The threaded portion of the insulator should have the same dimensions and taper as that of the pin.

Shoulder.—It is proposed to make the shoulder $\frac{3}{16}$ inch on all pins. That is, the diameter of the pin just above the cross arm will be $\frac{3}{8}$ inch greater than the nominal diameter of that portion of the pin in the cross arm; it is proposed to carry this diameter $\frac{1}{4}$ inch above the cross arm before tapering the pin.

Dimensions in Cross Arm.—It is proposed to make the diameter of that portion of the pin in the cross arm, just below the shoulder, $\frac{1}{32}$ inch less than the diameter of the hole in the cross arm and at the lower end of the pin $\frac{1}{16}$ less than the diameter of the hole in the cross arm. It is proposed, also, to designate this portion of the pin as having a nominal diameter equal to that of the hole in the cross arm into which the pin fits. Therefore, that portion of a pin which is to fit a $1\frac{1}{2}$ inch hole in a cross arm will have a nominal diameter of $1\frac{1}{2}$ inch but will have an actual diameter just below the shoulder of $1-15/32$ inch, and at the lower end of the pin of $1-7/16$ inch.

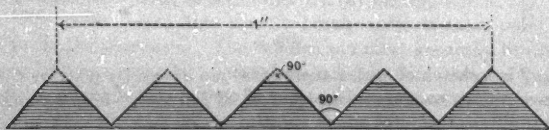


FIG. 3.

Thread.—It is proposed to use on all pins a thread having a pitch of $\frac{1}{4}$ inch or 4 threads to the inch, the form of thread to be that shown in Fig. 3 (scale four times full size). As there shown,

the angle between the faces of the thread is 90° and the top of the thread is flattened by cutting off, from the form the thread would have if not flattened, one-fourth its unflattened depth. The form of the thread in the insulator should be the same as that on the pin. If this is done it will insure the bearing surface being always on the sides of the threads and never on the edges.

Designation.—It is proposed to designate that portion of the pin above the cross arm as the "stem" of the pin. That portion in the cross arm as the "shank" of the pin. It is proposed to designate a pin by the length of its stem, *i.e.*, a pin whose stem is 5 inches long will be designated as a "5" inch pin, one 6 inches long as a "6" inch pin, etc.

Dimensions of Standard Pins.—In accordance with the above the following table has been prepared, giving a number of sizes of pins, and their dimensions, which it is proposed to make standard. The diameter of the shank has in each case been fixed by making it approximately equal to (slightly larger than) the diameter of the theoretical pin corresponding to the length of the stem of the pin in question. The headings of the columns of the table refer to the lettering of Fig. 4. Fig. 4 is a full size unthreaded 5 inch (proposed standard) pin.

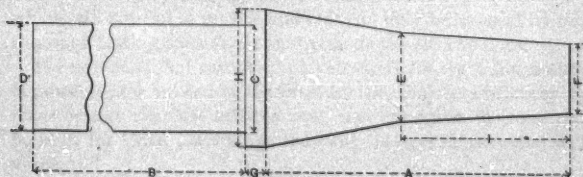


FIG. 4.

Size of Pin.	A	B	C Nominal.	C Actual.	D	E	F	G	H	I
5"	4 $\frac{1}{4}$ "	4 $\frac{1}{4}$ "	1 $\frac{1}{4}$ "	1 $\frac{1}{4}$ "	1 $\frac{1}{4}$ "	1 $\frac{1}{4}$ "	1"	1"	1 $\frac{1}{4}$ "	2 $\frac{1}{4}$ "
7	6 $\frac{1}{4}$ "	4 $\frac{1}{4}$ "	1 $\frac{1}{4}$ "	1 $\frac{1}{4}$ "	1 $\frac{1}{4}$ "	Same for all sizes of pins.	Same for all sizes of pins.	Same for all sizes of pins.	2 $\frac{1}{4}$ "	Same for all sizes of pins.
9	8 $\frac{1}{4}$ "	4 $\frac{1}{4}$ "	1 $\frac{1}{4}$ "	1 $\frac{1}{4}$ "	1 $\frac{1}{4}$ "				2 $\frac{1}{4}$ "	
11	10 $\frac{1}{4}$ "	4 $\frac{1}{4}$ "	2	1 $\frac{1}{4}$ "	1 $\frac{1}{4}$ "				2 $\frac{1}{4}$ "	
13	12 $\frac{1}{4}$ "	4 $\frac{1}{4}$ "	2 $\frac{1}{4}$ "	2 $\frac{1}{4}$ "	2 $\frac{1}{4}$ "				2 $\frac{1}{4}$ "	
15	14 $\frac{1}{4}$ "	4 $\frac{1}{4}$ "	2 $\frac{1}{4}$ "	2 $\frac{1}{4}$ "	2 $\frac{1}{4}$ "	Same for all sizes of pins.	Same for all sizes of pins.	Same for all sizes of pins.	2 $\frac{1}{4}$ "	Same for all sizes of pins.
17	16 $\frac{1}{4}$ "	5 $\frac{1}{4}$ "	2 $\frac{1}{4}$ "	2 $\frac{1}{4}$ "	2 $\frac{1}{4}$ "				2 $\frac{1}{4}$ "	
19	18 $\frac{1}{4}$ "	5 $\frac{1}{4}$ "	2 $\frac{1}{4}$ "	2 $\frac{1}{4}$ "	2 $\frac{1}{4}$ "				2 $\frac{1}{4}$ "	

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THE TESTING OF INSULATORS.

BY F. O. BLACKWELL.

A statement of the requirements for satisfactory insulators and recommendations as to apparatus and methods of carrying on insulator tests.

An electric power transmission cannot be successful unless it is able to deliver uninterrupted power.

Continuous operation, so far as the transmission line is concerned, depends largely upon the effectiveness of the insulator which is employed. Insulators must, therefore, be obtained which will not fail in service and this can only be assured by the thorough testing of each one that goes on the electric lines.

The potential that can be employed safely for the transmission of power is now limited by the pressure the insulators will bear as transformers that are reliable and not excessive in cost can be built for twice the voltage that any line yet constructed will withstand.

As the distance over which power can be transmitted with a fixed cost of conductor varies with the potential, the length of transmission lines is to a great extent limited by the insulator.

The design of new and improved types of insulators is, therefore, most important, and these can only be developed by experiment with adequate testing facilities. In order to ascertain the value of such insulators, no method of testing can equal a practical trial under conditions of actual service. Placing new insulators on power transmission lines in commercial operation is impracticable in most cases and should only be permitted after they have successfully withstood tests to demonstrate their

ability to stand operating conditions. These tests should duplicate as nearly as possible the electrical and mechanical strains set up in the insulators under the most severe conditions that would ever be met with on a transmission line.

There are certain facts which must be considered if correct deductions are to be made from insulator tests. For instance, we cannot test each insulator with a given number of volts continuously as it would be in service. As is well known, all insulating materials are most apt to break down on long applied electric stress. The prepared cloth wrappings used on the windings of electrical machinery will stand instantaneously two or three times the potential that they will carry continuously. Glass and porcelain are not affected by time to the same extent as organic materials, but we know that both kinds of insulators have been punctured by long continued applications of lower pressures than those which they have withstood in tests of short duration.

The shape of the potential wave also has a pronounced effect in breaking down insulation. A wave may be either flat topped or peaked, so that the maximum instantaneous potential is much less or greater than that of a sine wave of the same square root of the mean square potential. We might have for the same potential as read by the voltmeter, maximum instantaneous potentials which differ as much as two to one.

In air, the maximum point of the wave determines the distance which the current will jump. Different generators or even the same generator under different conditions of load will show widely varying arcing distances for the same potential.

Insulating materials being more affected by time than air, show in their ability to resist puncture that the average potential of the wave is more important than the maximum.

It is not safe to assume the potential either by the voltmeter or air gap as the true potential for determining the insulating value as it is somewhere between the two. Moisture in the atmosphere also effects the arcing distance. In steam, a given potential will jump twice as far and in a fog 25 per cent. farther than under ordinary conditions. Of course, if the altitude is high and the air more rarified, the arc will also jump a greater distance.

I would like to call attention to the characteristics of the apparatus required for testing insulators.

The alternators generally used for long distance transmission plants give very nearly a sine wave and therefore the testing generator should be one which will give a sine wave under all

conditions. It is not sufficient to do so at full potential and no load, as tests are made with all degrees of excitation and with both leading and lagging currents.

The armature reaction should be as small as possible, which means that the generator should be much larger than would ordinarily be thought necessary. It is also desirable to have a high reluctance in the magnetic circuit to secure stability when running with weak fields and permit of control with a reasonable amount of field resistance.

There should be but one transformer used to step up to the highest potential required and its reactance should be as low as possible. A number of transformers in series is particularly bad, as it gives poor regulation and leads to great uncertainty as to the actual potential to which an insulator is being subjected.

I have known testing sets with transformers in series and a generator of poor regulation to vary widely in the relation of the generator volts and the length of the spark gap due to change of wave form with different magnetic saturations of the apparatus and different numbers of insulators and consequently various capacities on the testing circuit. The only certain way to determine the real potential is to have a step-down instrument transformer on the high potential circuit.

Assuming that insulators are to be passed upon for a specific transmission plant, they should first be inspected to see that they are free from cracks, bubbles or pits that will impair their strength or in which moisture can lodge. If of porcelain, the glaze should cover all the outer surfaces. The glaze is of no insulating value in itself, but dirt sticks to unglazed surfaces.

Experience has shown that porcelain insulators which are not absolutely non-absorbent are worthless. The best porcelain shows a polished fracture like glass. If there is any doubt about the quality of the porcelain in this respect, it should be broken into small pieces, kept in a hot dry place for some time, weighed and immersed in water for a day. When taken out of the water the weight should be the same as at first. A puncture test should be made by setting the insulator in a cup of salt water, filling the pin hole also with water and slowly increasing the potential between the top and bottom until the desired test potential is reached or the insulator either punctures or arcs over the surface.

If an insulator is built up of several parts, each part should be able to withstand a pressure greater than it will have to sustain

when the complete insulator is tested. If it is to be tested for 100,000 volts and is made in two parts, each part might, for instance, be tested with 70,000 volts. The object of this is to have the weak parts rejected before they are assembled. A fair puncture test for an insulator is twice the potential for which it is to be employed, applied between the head and the interior for one minute. For example, the insulators for a 50,000 volt line should each stand 100,000 volts. As the potential from any wire to ground on a 5000 volt three-phase system would only be about 30,000 volts, a 100,000 volt test gives a factor of safety of nearly three and one-half to one. If one branch were grounded, as sometimes occurs in practice, the factor of safety would be but two to one. A one-minute test is not so severe as a continuous application of an equal potential, but insulators that have passed this test stand up well in service.

New types of insulators should be mounted on iron pins and tested both wet and dry, to determine the potentials which will arc over them. The dry test is of little value, as the potential at which the arc jumps from the head to the pin can be predetermined by measuring the shortest distance between them and referring to a curve of arcing distances in air. In a wet arcing test, a stream of water from a sprinkler nozzle under a pressure of at least 50 pounds to the inch should be played on the insulator at an angle of say 30 degrees from the horizontal. This will be similar to the condition which exists in a rain and wind storm. The insulator should not arc over from the wire to the pin at less than the potential which will exist in service between any two conductors.

In no case should wooden pins be relied on for insulation, as their value is only temporary. All wooden pins in time become dirty, absorb moisture and eventually burn off unless the insulator is good enough to be used with an iron pin. If an insulator is going to fail, it is better to have it do so at the start and not interrupt the service by breaking down perhaps years afterwards.

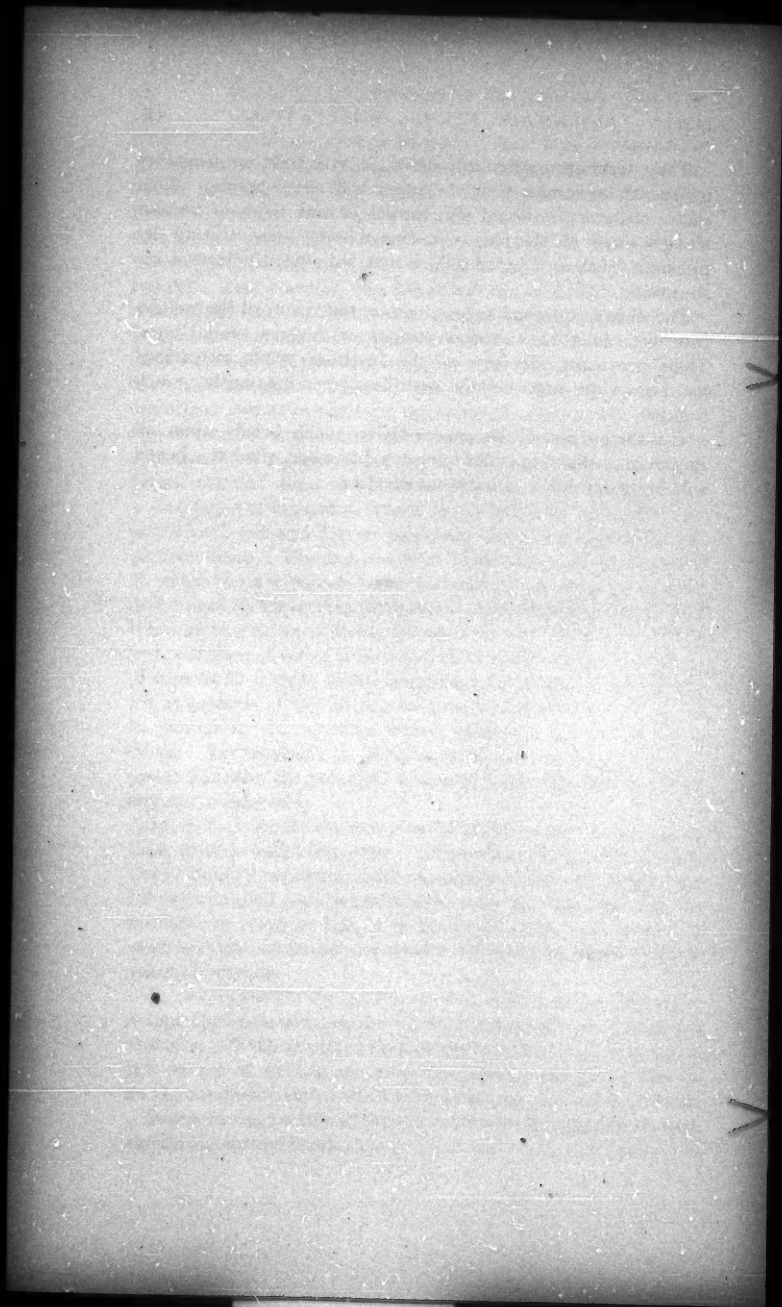
In addition to the electrical tests, it is well (if the insulator is of a type that seems to require it), to try samples for mechanical strength. When mounted on pins the insulator should stand a side strain of at least ten times the pressure exerted by the air on the conductor with a wind velocity of, say, 100 miles an hour.

It should also be able to slip the conductor through the tie wire should the former break.

These tests are particularly desirable with built-up insulators in order to be certain that the parts will not separate. With such insulators, it would also be well to test them in tension along the axis of the pin as in transmission lines crossing depressions, such an upward pull is not infrequently exerted on the insulator.

The above notes and suggestions are the result of the writers tests of insulators, and observations of high potential lines. There are many members of the Institute whose experience has been wider and who have doubtless given the matter much thought.

It is the purpose of this paper only to touch briefly upon an important subject in order to open a discussion which it is hoped will bring out much valuable information.



TRANSPPOSITION AND RELATIVE LOCATION OF POWER AND TELEPHONE WIRES.

BY P. M. LINCOLN.

A consideration of the causes of electrical disturbances in telephone lines which parallel high tension lines, and of means for reducing these disturbances.

(1) The extraordinary sensitiveness of the telephone receiver makes this instrument peculiarly susceptible to electrical disturbances. One authority states that the energy used in a sixteen candle power incandescent lamp is sufficient to produce an audible sound in thirty billion receivers. The methods, therefore of shielding telephone wires from the inductive effects of neighboring wires become important. Particularly is this true in the case of a telephone line paralleling a high tension transmission line, where the inductive disturbances are apt to be large, and uninterrupted service on the telephone line important.

(2) The remarks and discussion in this "Introduction to Discussion" apply particularly to telephone lines paralleling high tension lines, but comments hereon need not be restricted to such cases.

(3) There are three ways in which disturbing current in telephone circuits may be caused by the high tension circuit.

- (1) Electromagnetic induction.
- (2) Electrostatic induction.
- (3) Leakage.

It is the first two causes of disturbances which will claim particular attention in the following discussion.

(4) Electromagnetic induction may be briefly described as a transformer action. In Fig. 1 let a , b and c be the conductors of a three-phase line, and m and n the two wires of a paralleling telephone circuit. a and b may then be regarded as the primary and m and n as the secondary of a transformer. The e.m.f. in circuit mn will depend, among other things, upon the amount and frequency of the current in the inducing circuit. By transposing m and n in the well-known manner, the e.m.f.'s set up in one part of the telephone circuit will be neutralized by equal and opposite e.m.f.'s set up in other parts. Thus, the electromagnetic effects between m and n may be entirely neutralized by trans-

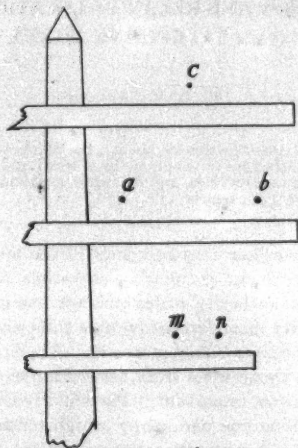


Fig. 1

posing the telephone wires only, regardless of whether the transmission wires are transposed or not. It may be well to note, however, that while the e.m.f. between the two telephone wires may be reduced to zero by properly transposing the telephone wires only, the e.m.f. between the two telephone conductors considered as one side of a circuit and the earth as the other, can be reduced to zero only by transposing the power wires. This point is of little importance, however, as any electromagnetic e.m.f. between the telephone wires and ground is entirely overshadowed by the electrostatic which will be considered later.

(5) Electrostatic effects will also take place in m , n , due to transmission circuit a , b , c . If conductor a has a minus charge

for instance, it will induce a certain plus charge on m and a smaller plus charge on n , on account of n 's greater distance from a . If now the minus charge be removed from a , current will flow from m to n , proportional to the difference in the amounts of these charges. The electrostatic influence of b , being opposite a in sign, will reinforce the action of a . Transposition of the telephone wires will have the effect of neutralizing this tendency of setting up electrostatic currents between m and n . It is important to note that a system of transpositions designed to correct electromagnetic induction between the wires will also be correct for electrostatic induction.

(6) Considering the comparative electromagnetic and electrostatic disturbances in a section of untransposed telephone line, it may be interesting to observe that the first is in the nature of a constant potential effect and the second of a constant current effect. It is evident that induced electromagnetic e.m.f. is constant as long as the inducing current is constant. As for the electrostatic effect, it is evident that the amounts of the induced charges on m and n , and therefore the electrostatically induced current between them, will not become appreciably reduced until the current flowing between m and n makes a difference of potential between them appreciable, compared with the inducing difference of potential. With telephone receivers of varying resistance, therefore, the ampere turns in the receiver due to electromagnetic induction are practically constant, while those due to electrostatic induction increase with number of turns and therefore the resistance of receiver. The electrostatic and electromagnetic effect become roughly equal with an arrangement shown in Fig. 1, when a, b, c is a line carrying 50 amperes at 20,000 volts, and the telephone circuit contains a total resistance of 1,000 ohms, including receivers.

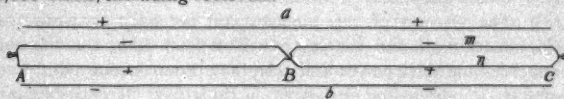


Fig 2

(7) The bridged telephone has almost universally taken the place of the series instrument for all telephone work. The series telephone is particularly objectionable for use on a circuit in which static induction takes place to any great extent. The reason for this is seen by an inspection of Fig. 2. The telephone

wire m has between A and B a plus charge induced and between B and C a minus charge. There is, therefore, at the transposition point B a flow of current from one section of m to the other. If now a series telephone be placed in series with m at B , it not only gets the benefit of this charging current between the two sections of m , but it also creates a difference of potential and, therefore, disturbing currents in telephones at A and C as well.

(8) Although a proper system of transposition will prevent the establishment of an induced e.m.f. *between* the two telephone wires, it does not necessarily prevent the two wires from assuming a potential which differs from that of the earth. In a properly transposed system, each telephone wire is the same average distance from each power wire. The potential, therefore, which the telephone system tends to assume from the static induction of the power wires is that of the neutral point of the power system. By neutral point is meant that point between which and each of the power wires the average e.m.f. is the same. Under normal conditions this neutral point is at ground potential. If, however, leakage takes place from one of the power conductors to ground, this neutral point will differ in potential from the ground and the amount of this difference becomes greater as the resistance of the leak becomes less. In a three-phase system, when the resistance of this leak becomes zero, the maximum difference of potential between the neutral point and ground occurs, and is 58 per cent. of the power circuit voltage. In a 20,000 volt system, for instance, there may exist a potential of nearly 12,000 volts between the neutral point and ground. When the neutral point of the power line differs in potential from the ground, an electrostatic difference of potential tends to exist between the telephone wires and earth, and will exist if the insulation of the telephone circuit is perfect.

(9) The amount of this electrostatic potential between the telephone circuit and the earth will depend upon the relative capacities between power and telephone lines on one hand and between telephone line and earth on the other. The power and telephone lines may be considered as opposite plates of one condenser and the telephone line and ground as opposite plates of another condenser. These two condensers being in series, they will distribute the total e.m.f. in inverse ratio to their capacities. With usual construction, the capacity between telephone line and ground will not be less than that between telephone and power wires, so that the potential, of the telephone wires above ground

will be equal to at least one-half the potential of the power line neutral point above ground. A grounded power line may thus cause a potential between the telephone wires and ground which will reach well into thousands of volts, and even a bad insulator may cause such an e.m.f. measured by hundreds of volts. In this connection it is significant to note that in the great majority of cases the telephones become inoperative when a ground occurs on the power lines. Is it any wonder? How many telephone lines are built to stand up under a strain of even 1,000 volts, let alone 5,000 or 10,000 volts to ground? It is hardly necessary to point out the path of the disturbing currents. The first voltage strain comes not between telephone wires, but between the two wires and ground. A break down of its insulation, either partial or complete, occurs at some point, and the wire to which the break occurs discharges to ground either partially or completely, and the other wire must discharge *through the telephones* to ground.

(10) The points, therefore, which deserve careful consideration in the installation and operation of a telephone line when it is to be operated in proximity to a high tension transmission line are the following:

- (1) Insulation.
- (2) Transpositions.
- (3) Use of bridge telephones instead of series telephones.
- (4) Making static capacity of telephone wires to ground as great as possible, and capacity to power wires as small as possible.

(1) *Insulation.*

(11) Insulation is put first as being the point of first importance. A ground on the transmission line is going to cause either volts or trouble on the telephone line. There is no reason why the telephone wires will not transmit speech properly, even if it does differ in potential from the ground. But to obtain this result, disturbing currents from the line to earth must be prevented by perfect insulation. When it is realized that the potential between the telephone line and ground may be as high as 30 per cent. of the potential between power wires, the importance of insulation is better understood. By insulation, too, is meant the insulation throughout the entire line. There is little use in providing glass insulators for pole supports capable of standing a voltage of 15,000 or 20,000 and then inside buildings attaching the telephone wires directly to woodwork which may be damp, or

to an instrument mounted on a damp brick wall. Above all, there is no use in putting up a line which may be able to stand a test of 15,000 or 20,000 volts, and then attach to this same line a lightning arrester which will break down at 300 volts, as the standard telephone lightning arrester is expected to do.

(12) When providing high tension insulation for the telephone line, the insulation of the man using it should not be forgotten. This insulation of the telephone user is advisable, not only to protect him from the induced voltage but also to protect him in case of a cross with the power line. The induced voltage is not so dangerous as its amount would indicate because the current is limited to that of a condenser consisting of power line, as one plate, and the telephone line as the other. It may be noted that the telephone insulation is subjected to high strains only when the power line is grounded or heavily unbalanced statically. This is just the time, however, that uninterrupted service of the telephone line is apt to be of the utmost importance.

(2) Transpositions.

(13) The necessity of transposing the telephone line is almost so apparent as not to need comment. Otherwise continuous disturbances will exist, due both to electromagnetic and electrostatic effects. So far as the telephone line is concerned, transposition of the power wires is not so important. An untransposed power line cannot induce either electrostatic or electromagnetic effects between two transposed telephone wires, but only between these two wires and ground. The amount the statically balanced untransposed power line can elevate the telephone wires above the ground potential is small compared to the effect of the power line when statically unbalanced, whether transposed or untransposed. If the telephone line is insulated to meet the worst conditions, it will be ample to meet the normal condition of an untransposed power line.

(3) Use of Bridge Instead of Series Telephones.

(14) This point is one which need only be mentioned. The advantages of the bridged over the series telephone are so well known that the reason before mentioned for using a bridged instead of a series instrument is simply throwing another shovelful of earth on the grave of the series instrument.

(4) Making Capacity of Telephone Wires to Earth as Great as Possible, and Telephone Wires to Power Wires Small as Possible.

(15) In Montana there is a line in operation at 50,000 volts.

Other lines are projected as high as 60,000 to 80,000 volts, and there is a possibility of going higher. When one realizes that with the usual construction as shown in Fig. 1, there may be in such cases an elevation in the potential of the telephone wires of 20,000 to 25,000 volts above ground he begins to cast about for some method of reducing this potential. The total voltage between the neutral point of the power wires and ground may be considered as taken up across two condensers, one consisting of the power and telephone wires, and the other the telephone wires and earth. To decrease the possible potential of the telephone wires to ground, therefore, one must either decrease the capacity of the power wire—telephone wire condenser, or increase the capacity of the telephone wire—earth condenser, or both. This may be accomplished by increasing the distance between power and telephone wires, and decreasing the distance between telephone wires and earth. If the same supporting structure be used, there is a limit to which this can be carried, at which the possible voltage between telephone wires and earth may be still prohibitive. The capacity of the telephone wire-earth condenser, may be still further increased by bringing the earth to the telephone wires, instead of the telephone wires to earth. That is, one or more ground wires may be run in close proximity to the telephone wires, thereby increasing the capacity of the telephone wire-earth condenser, to almost any desired limit. By this means the possible potential between telephone wires and earth may be brought within limits where it may be taken care of with safety.

(16) In conclusion, the writer asks for the freest comments on the foregoing remarks, particularly from those who have had experience in operating a telephone line paralleling high tension wires. If such can agree with the writer in his remarks, he will be pleased to know it. If they cannot agree, he will be still more pleased to find out wherein he is wrong.

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BURNING OF WOODEN PINS ON HIGH TENSION TRANSMISSION LINES.

BY C. C. CHESNEY.

Facts concerning a number of examples of
the burning of wooden insulators pins and a
recommendation as to the use of iron pins.

In this country it has been almost the uniform practice in high tension pole line construction to use wooden pins. The reason for their use has been the belief that because they were made of wood they strengthened the entire insulation of the pole line system, and were in consequence additional safeguards. These pins have generally been made of locust, oak or eucalyptus, and in order that the insulation might not deteriorate from the action of the weather, they have usually been treated carefully with hot asphaltum, paraffine or linseed oil. The temperature and character of the treating liquid have depended more or less upon the whim of the constructing or designing engineer. Although there has been no uniform method followed and although the materials used in the treatment have differed greatly, the results have been universally the same. Wood pins when used with glass or well vitrified porcelain insulators, have given very good service on potentials as high as 25,000 or 30,000 volts. There have been no unusual pin troubles at these voltages which could not readily be explained by porous or cracked insulators or by some peculiar climatic conditions. In my opinion, the success secured in the operation of the great majority of these lines is due to good insulation of the insulator, and the insulation of the pin has in reality contributed very little to that success. For 40,000 volts and for higher potentials, the insulators offered by all manufacturers do not have the same factors of safety as

pole and occupied the relative positions as shown in the cuts. The burned sides stood towards the damp winds from the ocean. Fig. 6 shows a burned pin of the type shown in Fig. 2. Fig. 7 is the Locke iron-pin with porcelain base (Fig. 3) taken from a 33,000 volt line. The striking feature is the burning of the wooden thread to the iron pin. The writer has been informed by the general superintendent of this plant that every pin that has been examined on this line is burned in exactly the same way, yet

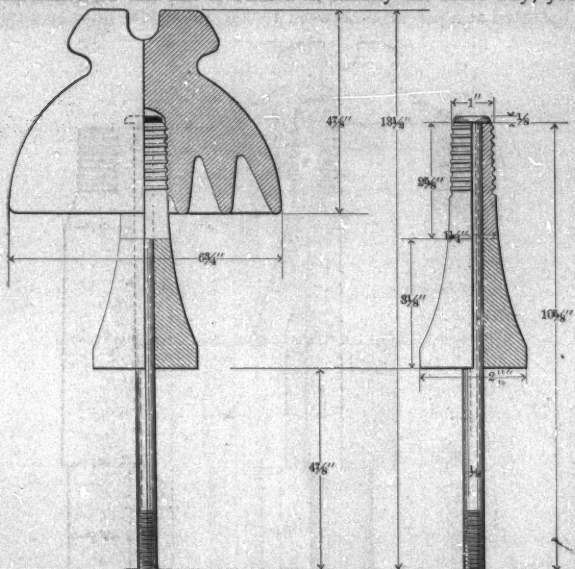


FIG. 3.

there has been comparatively few punctured insulators and no cross-arms burned from the current leaking over the surface of the insulators. Fig. 8 shows the pin taken from the same 50,000 volt line as those shown in Fig. 4. This pin is shown sawed in sections in Fig. 9. The noticeable feature is that the burned section is entirely in the upper part of the pin about 1 1/4" below the thread. The outside surface and the centre of the pin below this point shows no charring. It would appear that at least in this instance, the burned section was the point of highest resistance of the pin, and that the lower part of the pin was a good

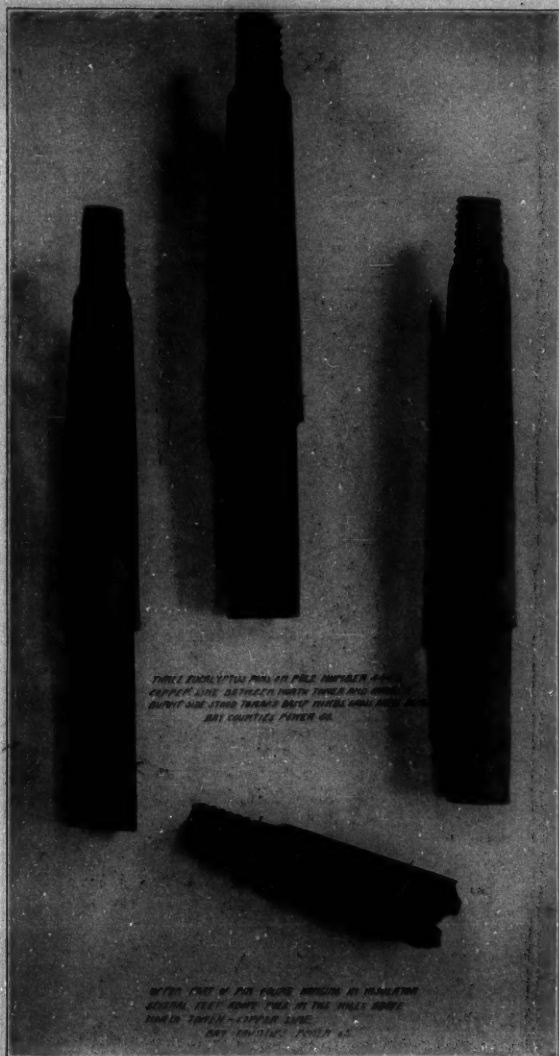


FIG. 4.

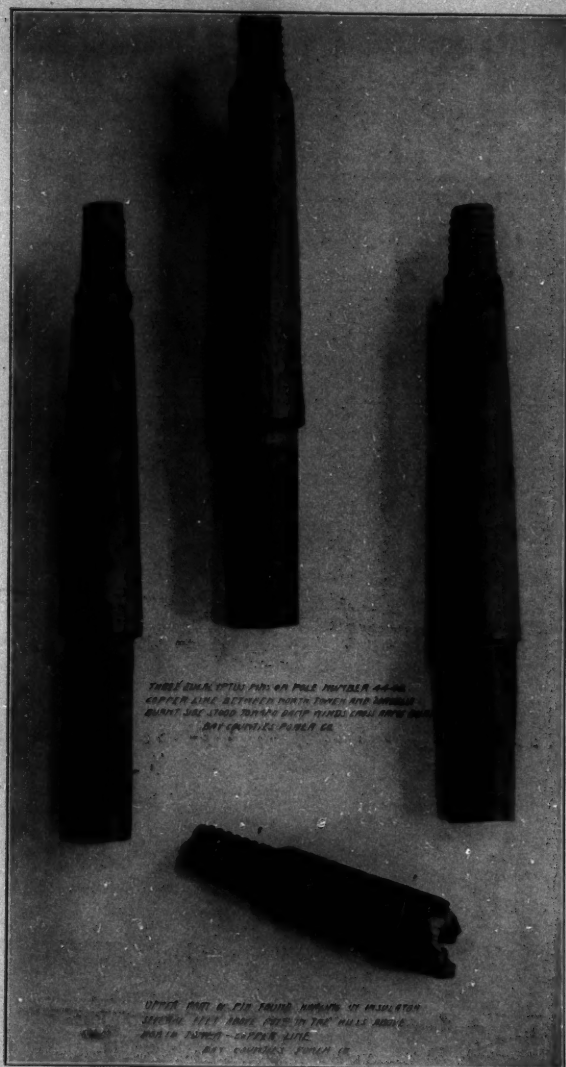


FIG. 5.



Fig. 6

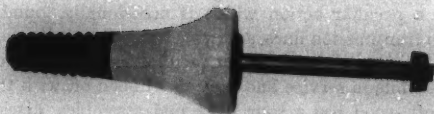


Fig. 7



Fig. 6



Fig. 10.

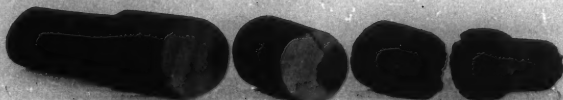


Fig. 9.

enough conductor to permit the small current which leaked over the surface of the insulator to flow without any special generation of heat in that section of the pin. The reduced insulation of the pin and insulator was no doubt due to the dust and fog. The upper portion of the pin, being better protected by the insulator from fog and dust, had in consequence higher surface resistance. The dark spot shown on the right hand edges of the lower section of Fig. 9 is the sap section of the wood and has been discolored by the linseed oil boiling which the pin originally had. This section has been in no way affected by the current. In Fig. 9 is illustrated a peculiar action which is occasionally found on high tension transmission lines, and which, for a better name, has been called "digesting the thread of the pin." The thread of the pin softens while in service and may be rubbed off with the fingers. This soft wood has a sour taste and resembles digested wood pulp. This action is not necessarily accompanied by the burning of any portions of the pin.

The evidence here presented, while not conclusive, still points to the advisability of using iron pins with modern insulators properly chosen for the line potential.

MODEL SHOWING DISTRIBUTION OF ELECTROMOTIVE FORCE AND CURRENT ALONG A SINGLE PHASE ALTERNATING CURRENT TRANSMISSION LINE.

BY W. S. FRANKLIN.

A helical line drawn on the surface of a transparent cylinder and set rotating about its axis would appear to an observer looking at it from one side as a wave line traveling along the axis. The direction of travel of this wave line would be one way or the other, according as the helix is right or left-handed.

A rotating right-handed helix would represent the electromotive force waves (or the current waves) traveling outwards from a generating station along a transmission line having inductance and capacity, but having neither resistance nor leakage.

A left-handed helix rotating in the same direction about the same axis would represent the electromotive force waves (or the current waves) reflected back from the receiver. A compound helix of which the radius vector at each point along the axis is the sum of the radii vectores of the two simple helices would, if set rotating, represent the actual distribution of electromotive force (or current) along the transmission line.

The effect of line resistance and line leakage is to cause the waves of electromotive force and current to diminish in amplitude as they travel along the line.

Imagine a helix-like line drawn about an axis, the radius vector of this helix-like line at a point along the axis being proportional to e^{-x} where e is the Napierian base and x is distance measured along the axis from one end. If this helix-like line is set rotating about the axis, it will appear to an observer looking at it

from one side as a wave line traveling along the axis and diminishing in amplitude as it travels along.

A rotating, right-handed helix-like line of the kind just specified would represent the electromotive force waves (or the current waves) traveling outwards from a generating station along a transmission line having inductance, capacity, resistance and leakage.

A left-handed helix-like line rotating in the same direction about the same axis would represent the electromotive force waves (or the current waves) which are reflected back from the receiver.

A compound helix-like line of which the radius vector at each point along the axis is the vector sum of the radii vectores of the two single helix-like lines, would, if set rotating, represent the actual distribution of electromotive force (or current) along the transmission line.

The model which is herewith exhibited contains: (A), Two simple and one compound helix-like lines, which represent outgoing, reflected, and resultant electromotive force waves respectively; and (B), Two simple and one compound helix-like lines which represent outgoing, reflected, and resultant current waves respectively.

This model was calculated and constructed by Messrs. J. H. Flory and C. W. Startzman, as a graduating thesis in electrical engineering, at Lehigh University in 1901.

The calculations were based upon the following data:

Length of line, 200 miles.

Resistance of line one ohm per mile.

Reactance of line due to inductance four ohms per mile.

Leakage conductance of line, 0.00002 mho's per mile.

Capacity susceptance of line, 0.0002 mho's per mile.

Receiver is a condenser having a reactance value of 100 ohms.

The actual value of electromotive force (or current) is not essential to the interpretation of the model but as a matter of fact the voltage at the terminals of the receiving circuit was taken to be 10,000 volts and the current, of course, 100 amperes.

DISCUSSION.

PRESIDENT SCOTT:—The subject of the meeting this evening is Power Transmission on High Tension Lines.

There are a number of different subjects to be presented; these have been prepared by the members of the Transmission Committee as introductions to discussions, not as complete, formal and exhaustive papers in themselves, but written with the intent of calling attention to and introducing a number of points on the several subjects which would lead to contributions from others. Mr. Mershon and I think that the best method of conducting the meeting this evening would be to take up each subject in turn and to devote a specified time to it, so that some attention could be given to all. The gentlemen having the subjects in charge will have a certain amount of time at their disposal. They can present the written material first and then the subject will be open to general discussion for the remainder of the half hour which will be allotted to each of the subjects. The first topic is "Mechanical Specifications for a Proposed Standard Insulator Pin," by Ralph D. Mershon.

MR. RALPH D. MERSHON:—Before the discussion is begun, I wish to state that my object in writing this introduction was to get a discussion sufficiently full to form the basis of recommendation to the Standardization Committee.

There are a number of written contributions which I will read. The first is from Mr. M. H. Gerry, Jr., of the Missouri River Power Co.

MR. M. H. GERRY, JR.—It is too early in the development of high tension transmission to attempt to make standard the details of construction. Such action at this time by the INSTITUTE would

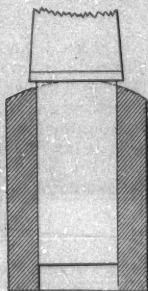


FIG. 1

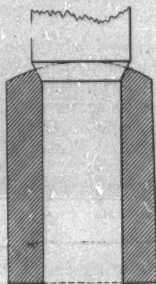


FIG. 2

result not only in failure, but in a tendency to prevent advancement in this line. However, a full discussion by the membership cannot fail to be of great advantage and profit.

Mr. Mershon has suggested the adoption as standard of certain forms of wooden pins, the designs of which conform to common

construction. Most engineers of experience, however, would be in favor of a diameter greater than one inch at the top of the pin, and a greater length of thread than two and one-half inches. Wooden threads most frequently fail by shearing, and the strength in this particular is greatly increased by a larger diameter of pin, and a greater length of thread. The longer thread is

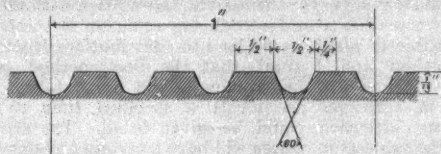


FIG. 3

an advantage also in preventing the insulator from tipping out of line, when the fitting is loose between the thread of the pin and that of the insulator.

The shoulder of the pin, as suggested by Mr. Merzhon, has certain disadvantages for heavy construction. On account of the rounding off of the top of the cross-arm, this form of shoulder

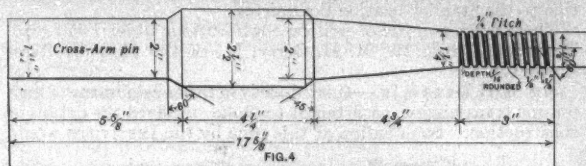


FIG. 4

does not bear well, as shown in sketch, Fig. No. 1, and the sharp corner at the point of greatest strain, introduces an element of weakness. In Fig. No. 2, a form of shoulder is shown which has been used by the writer with considerable success. This shoulder tapers at an angle of 60°, and fits into a counter-bore in the top of the cross-arm. With this design the pins may be driven to a

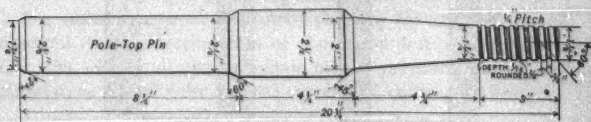


FIG. 5

firm bearing at the top of the cross-arm, which has the effect of steadying them and increasing the strength of the construction at this point.

In lieu of the form of thread proposed by Mr. Merzhon, the writer suggests that shown by sketch, Fig. No. 3. In this design

the square top of the thread is as wide as the groove, resulting in increased area of wood to withstand shearing strains. The threads of the insulators are always stronger than those of the pins, and for this reason the form of thread as proposed has considerable advantage. This form of thread may also be easily cut, in either seasoned or unseasoned wood, and the depth not being so great the pin is stronger at the bottom of the thread.



FIG. 6.

Figs. No. 4 and No. 5 are drawings of the high-tension pins now used by the Missouri River Power Company. They show the form of the thread and of the shoulder as described above, and also give the general dimensions of the pins. The upper shoulder as shown by the drawings is for the support of a glass sleeve, which is used to protect the pin from the weather. Fig. No. 6 is from a photograph of the 50,000 volt line insulator assembled on one of the pins.

MR. MERSHON:—The next written contribution is by Mr. William R. C. Corson, Electrical Engineer, of Hartford, Conn.

MR. WILLIAM R. C. CORSON:—I believe I am only concurring with the general feeling in expressing my pleasure that our Committee on High-Tension Transmission has seen fit to commence its work by an effort to standardize an essential element of construction, and in hoping that this line of effort may be continued and result in recognized and approved standards for all other items capable of a general determination.

Mr. Mershon's method of developing the table of dimensions of the proposed pin is so rational that criticism of it is difficult. Briefly stated, of course, this method assumes the pin in general use as a basis, and mathematically determines the diameters of pins of differing length, which shall be capable of sustaining the same tension at their extremity as will this pin. In other words, the safe load that may be applied at the top of the proposed pins is of constant value in all. This value is not discussed in the "Introduction," and feeling that its determination would be of interest to me, and might prove of value, I have made a series of tests in a Sellers' machine to ascertain the value of s in equation (1,) for the ordinary locust pins, under the actual conditions of support suggested.

Six standard locust wood pins were selected at random from a supply at hand. The larger diameter of the shank varied from $1\frac{7}{16}$ inches to $1\frac{1}{2}$ inches, while the smaller diameter was uniformly $1\frac{11}{32}$ inches. These were supported in a $1\frac{1}{2}$ inch hole in a hard wood block, and the measured tension applied about $4\frac{1}{2}$ inches from the block, the exact distance of the point of application being measured.

The load was very gradually applied in increments of a few pounds, and the amount noted when the first separation of the fibre appeared. Most of the specimens showed distress at from 700 to 750 lbs., with maximum strength of about 10 per cent. above this. One specimen, however, showed a crack at 600 lbs., and an ultimate strength of 1083 lbs. The average value of s determined from the tension at which the first fibre separation appeared was 11,130 lbs. per sq. inch, and the average value calculated from the maximum loads sustained was 13,623. The value of s , calculated for the specimen crackling at 600 lbs., was 9,280. While this is somewhat below the average due to an apparent defect in the wood, it is probably best to assume that for a maximum load, s should not be greater than 9,000. Assuming this value, the maximum load that may be applied to the proposed pins at a distance from the cross-arm equal to the designation of size, would be as follows:

Size of Pin.	Value of P.	Size of Pin.	Value of P.
5 in.	557	13 in.	621
7 "	639	15 "	694
9 "	615	17 "	670
11 "	610	19 "	700

Of course these values of P would be identical but for the difference between the actual diameter selected and that of the theoretical pin. The average value is 636 lbs., which may be considered the maximum load that the standard pins will sustain at the point designated.

Even with very generous factors of safety, it would appear that the pins suggested would prove of ample strength to withstand the side strains to which they may be subjected. For heavy work and for end poles, an insulator carrying the wire at some distance below the top of the pin would, of course, increase the strength of the construction. A table of standard insulators could perhaps with advantage be prepared so proportioned between groove and bottom of threaded bore as to maintain the stress on the pin within the allowable safe values for the various tensions applied.

I would call attention to one seeming error in the table of the dimensions of the proposed pins. In the paragraph headed "Designation," the following appears: "It is proposed to designate that portion of the pin above the cross-arm as the 'stem' of the pin," and further, "It is proposed to designate a pin by the length of its stem." From this definition the stem of the pin would have a length equal to the sum of the dimensions A and G of the table. For the five-inch pin shown in the table this would be 5½ inches, and thus is not equal to the designation.

MR. MERSHON:—Another written contribution to this discussion is by Mr. C. L. Cory, of San Francisco.

MR. C. L. CORY:—The mechanical strength of insulator pins for use on long distance transmission lines has been given much consideration by electrical engineers in California during the past six years. For the most part, the insulator pins in use are wood. On the 33,000 volt, 83 mile, double circuit, three-phase transmission line of the Edison Electric Co., from their Santa Ana power house to the city of Los Angeles, iron pins with porcelain sleeves are used. This transmission is the most notable system in California at the present time using insulator pins other than wood.

Eucalyptus has been found to be perhaps the best wood to use for insulator pins. After being turned up and threaded, they are usually treated with hot linseed oil. This treatment is desirable more on account of the protection which such treatment gives the pin against weather than on account of the insulating qualities of the oil or oil treatment.

It should be understood in this connection that an insulator pin should be depended upon only to support the insulator. The insulator in turn should be depended upon to provide the necessary insulation for the line wires. No pin after being in use for a few years on a pole line can maintain to any marked degree the insulating qualities originally existing, due to such oil or paraffin treatment.

The tests outlined below were made in the electrical laboratory of the University of California, for the purpose of determining

how near the pins generally in use in California conform to the proposed standard pins suggested by Mr. Mershon. In the test twenty-two pins were broken. These were not selected particularly for the test, but were taken at random from a large lot of such pins which were to be used in construction work. Of these, twelve were of the size generally in use on transmission lines where the voltage does not exceed 30,000 volts. These pins are $11\frac{1}{2}$ inches long, including shank and stem, the latter being $6\frac{1}{2}$ inches in length. The other ten pins tested were of the size used on the lines of what has been known as the Bay Counties Power Co., now the California Gas & Electric Corporation, and the Standard Electric Co. The line voltage in each of these transmission systems is from 40,000 to 60,000 volts. These pins are

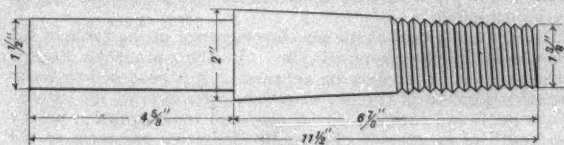


FIG. 1

$15\frac{1}{2}$ inches long, including shank and stem, the latter being $10\frac{1}{2}$ inches long. All of the dimensions of the pins tested are given in Figs. 1 and 2.

These pins do not exactly conform in size or length of stem with any of the proposed standard pins. Below, however, is given the comparative dimensions of the two samples of pins tested and the nearest sizes of the corresponding proposed pins. For sake of comparison, a 7-inch pin, as proposed, is contrasted with the $6\frac{1}{2}$ inch tested pin, and the 11 inch proposed pin is contrasted with the $10\frac{1}{2}$ inch tested pin. The above dimensions refer to the length of the stem of the pin, as suggested by Mr. Mershon.

COMPARISON OF PROPOSED PIN AND PINS TESTED.

	Size of Pin.	A	B	C Nominal	C Actual	D	E	F	G	H	I
Proposed Pin.	7"	7"	$4\frac{1}{4}$ "	$1\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	1"	$\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{1}{2}$
Pin Tested.	$6\frac{1}{2}$ "	$6\frac{1}{2}$ "	4"	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	—	2"	3
Proposed Pin.	11	11	$4\frac{3}{4}$	2	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	1"	$\frac{1}{4}$	$2\frac{3}{4}$	$2\frac{3}{4}$
Pin Tested.	$10\frac{1}{2}$ "	$10\frac{1}{2}$ "	$5\frac{1}{2}$	$2\frac{1}{16}$	2"	$2\frac{1}{16}$	$2\frac{1}{16}$	$1\frac{1}{2}$	$\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{1}{2}$

In general, it will be seen that the dimensions of the proposed and tested pin agree fairly well. The most marked difference is in the diameter of the portion of the pin which is threaded to

receive the insulator. It seems evident that one inch is not a sufficient diameter for the thread of the pin for all sizes. If there is any burning of the pin just below the insulator, the inevitable result will be breaking at the bottom portion of the thread. Such a break will usually leave the pin, except the threaded portion, standing in the cross-arm, while the insulator, with the threaded portion of the pin inside, will hang suspended on the line wire. This sort of break has often been observed on high-voltage transmission lines.

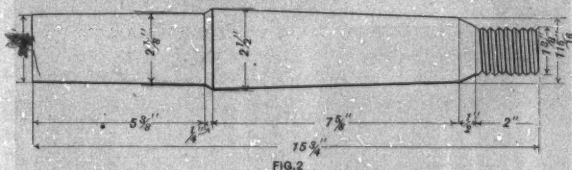


FIG. 2

The method of testing the pins is clearly shown in the accompanying photograph. It was impossible to mount the cross-arm in the testing machine so that the strain on the pin would be at right angles to its axis. The variation from a right angle, however, is small and to a certain degree conforms with the direction of the strain on the pin, due to the sag in the line wire. The "breaking load," as given in the tables below, refers to the strain in the direction of the cable, while the "real breaking load" is the component of this strain at right angles to the axis of the pin.

No.	Breaking Load.	Real Breaking Load.	No.	Breaking Load.	Real Breaking Load.
1	1010	950	1	2250	2120
2	1090	1035	2	3140	2960
3	1450	1360	3	2380	2240
4	1360	1280	4	2010	1890
5	920	865	6	2780	2620
6	1220	1150	7	2280	2140
7	1350	1270	8	1570	1475
8	940	875	9	2390	2250
9	1360	1280	10	3390	3190
10	1360	1280	Average.	2465	2310
11	750	705			
12	1060	1010			
Average.	1155	1085			

The average results, referring to the "real breaking load," of the tests of the two pins are respectively, 1085 pounds for the $6\frac{1}{8}$ inch pin and 2310 pounds for the $10\frac{1}{8}$ inch pin. The character

of break in the two pins, however, is not the same. Almost without exception, the $6\frac{1}{2}$ inch pins were broken approximately square off at the cross-arm. The larger pins, however, split in the stem, the beginning of the split being just at the bottom of the thread. An inspection of the photographs clearly shows the difference in the character of break in the two pins.



Method of Mounting Cross-Arms, Pins and Insulators in Testing Machine.

It seems from the tests that the shank is the weakest part in the $6\frac{1}{2}$ inch pins, while the stem, and particularly the upper portion of the stem, or thread, is the weakest part of the $10\frac{1}{2}$ inch pins.

The variation of the "real breaking load" for the different $6\frac{1}{4}$ inch pins tested is from 705 pounds minimum to 1360 pounds maximum. For the $10\frac{1}{4}$ inch pins, this variation is from 1475 pounds minimum to 3190 pounds maximum.

During the progress of the test, it was observed that the "allowable breaking load" was least when the pin was turned in the cross-arm, so that the strain was across the grain of the pin, while the greatest allowable "breaking load" corresponded with the position of the pin in the cross-arm, so that the strain was parallel to the grain of the pin. In the tests made, no particular care was taken to turn the pins in any fixed position relative to the grain of the pin and the direction of the strain applied.

For good construction on lines using 30,000 to 60,000 volts the larger pin must be used. It does not seem, however, that any good reason exists for a great number of different sizes of pins, as it would seem probable that the two sizes tested might be used to fulfil almost every requirement for transmission work where wooden pins are at all allowable.

In many respects an iron pin is better than one of wood. In the first place, to secure sufficient strength in the shank, the wooden pin must be of such a large diameter that the size of the cross-arm is necessarily increased. In addition, using an iron pin, the insulator can be held down on poles or supports where the tendency of the line wire is to raise or pull the pin out of the cross-arm. In using wooden pins, this is usually prevented by driving a nail through the cross-arm into the shank of the pin.

An iron insulator pin, possessing many desirable features, has been designed for use on the extensive transmission lines of the Vancouver Power Co., of Vancouver, British Columbia, the design being due to Mr. Wynn Meredith, of San Francisco. In general, the pin consists of a steel bolt approximately 12 inches long. A cast iron sleeve $4\frac{1}{2}$ inches long, and fitting closely to the cross-arm, fills the space between the thread, and corresponds to the stem of the ordinary wooden pin. The thread of the pin is made of lead, this lead thread being cast upon the end of the steel bolt, the steel bolt being first chopped or made ragged, so that the lead is held firmly to the steel bolt after being cast.

The tests upon this form of pin have not as yet been completed, but as soon as possible the results will be presented to the INSTITUTE.

MR. MERSHON:—The fourth and last written contribution to this part of the subject is by Mr. D. L. Huntington, electrical engineer of the Washington Power Company, Spokane, Wash.

MR. D. L. HUNTINGTON:—Wooden pins are subject to so many uncertainties when used in connection with very high voltages, especially where the atmosphere contains salt, smoke or dust, that it seems desirable to abandon their use for such purposes wherever possible, and to substitute a metallic pin. The construction of a long distance line for 60,000 volts, led the writer to make some investigation as to what could be done in this direction, without excessive cost.

It was decided that a drop-forged or a turned steel pin would be so expensive as to exclude it, even if the time at our disposal would have permitted us to wait for its delivery.

Experiments were made with a cast-iron pin almost identical in dimensions to that shown in Fig. 2 of Mr. Chesney's paper, except that it was cored out internally so as to make its weight about 10 pounds. The diameter of the shank was $2\frac{1}{8}$ inches. This pin, before fracturing, sustained a load slightly in excess of 3,000 pounds, suspended from near the end of the threaded portion.

Fear was felt, however, as to what might occur under the sudden strain of a line parting in winter time, with the possibility

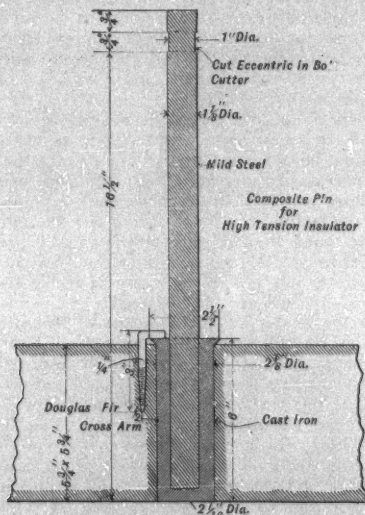


Fig. 1.

of the fracture of several pins at a time due to the sudden shock.

To avoid this, several designs were made of pins cut from round steel bars of 1 inch and $1\frac{1}{8}$ inch diameter. The difficulty in obtaining a satisfactory shoulder for the pin at the cross-arm proved serious. Furthermore, it was feared that with a pin of that small diameter, the cross-arm would be likely to burn out at the pin-hole, as the interior surface of the hole would be comparatively small for distributing the leakage currents to the cross-arm. Moreover, actual experience with wooden pins has shown more or less conclusively that with a shank diameter of

two inches or greater, there is little or nothing to fear from this trouble.

As a result of these several difficulties we have designed and adopted a pin (see Fig. 1) eighteen inches long, made of $1\frac{1}{2}$ inch round mild steel bar, and having a shoulder and shank cast upon it as shown. This pin we find will begin to bend when loaded with about 1,000 pounds at the upper end—the shank being rigidly supported. This is much lower than the results obtained by the cast iron pin referred to above, but it is believed that it is more reliable and that it is sufficient for nearly all ordinary work. In addition, the steel bar will not snap off under sudden shock, but will support the insulator and line safely even when badly bent. We were unable, in the time at our disposal, to investigate what could be done in the way of malleable castings of a design somewhat similar to the cast-iron pin mentioned above, but it is the writer's opinion that it would prove a fruitful line of investigation.

High freight rates of the west and a higher initial cost will doubtless make some of those in charge of the construction of such lines hesitate at the extra expenditure (in our case it was about double the cost of eucalyptus pins), but it is in the line of safe and conservative engineering and certainly strengthens the weakest link in our high-voltage chain, our lines.

MR. W. N. SMITH:—It seems to me that the dimensions given are all very well for a pin carrying a certain weight of wire, but it does not seem to me that a single standard table of dimensions could be laid down to cover anything like all the conditions of various power transmission lines, all the way from a line of 5,000 or 6,000 volts, with, say, No. 4 wire, up to one like the Niagara Falls power transmission line, which is of 300,000 c.m. cable. The scheme of the tabulation should be enlarged and gone over carefully, so as to have a separate tabulation for a reasonably small range of weights of copper wire to cable; that is, one table for sizes from No. 6 to No. 3, another No. 3 to No. 0, another from No. 0 to No. 0000, and another from No. 0000 up. In this way the design of a standard pin would more nearly meet the varying conditions of transmission line construction. I remember reading Mr. Stillwell's paper a year or more ago on the Niagara Falls transmission plant, in which, if I remember correctly, he stated that the principal trouble with pins was their breaking at the root of the thread. I do not see that this point has been covered in Mr. Merzhon's discussion, although it was referred to in Mr. Gerry's contribution. I should think it a matter of considerable importance in the design of the pin. I further agree with Mr. Gerry in his opinion that the top of the pin is rather small, certainly, for the very heavy insulators that would be required for a transmission above 30,000 volts.

MR. P. H. THOMAS:—It would be a great gain to those who hope to get information from the report of the committee, if the characteristics of the different types of wood commonly used

could be discussed, *e.g.*, oak, eucalyptus and locust. It is to be hoped that in the local sections this question will be very fully discussed. Also, something should be said about the method of treating pins, which is one of the most important questions in the insulation of the line. The treating of pins to make them waterproof, without injuring the mechanical strength, is a difficult matter.

In putting up an insulator, where the pin comes to a bearing on its end inside of the insulator, expansion of the pin or contraction of the insulator may crack off the top of the insulator, especially with glass. To amend this difficulty, a shoulder might be arranged so that the pin would not touch the top of the insulator.

MR. MERSHON:—As to the question of the size of the pin, it may be desirable to have a pin larger at the top, perhaps, but I do not think the reason which has been given for this holds very well. In the first place, an insulator properly designed will not tip. If the insulator is designed so that the side pull of the line on it is transmitted directly to the pin, instead of being all the way from an inch and a half to two inches above the top of the pin, as in the case of most insulators, it will not tip. If it does, that is a fault in the design of the insulator and not in the dimensions of the pin. Mr. Gerry has criticized the shearing strength of the thread. I doubt if the thread of the pin proposed by Mr. Gerry will have a greater shearing strength than the thread of the pin referred to in the paper. The question of the shearing strength is not so important. A well-designed line will not have much up-strain. A line with much up-strain is not laid out as it should be. You cannot prevent some up-strain on some insulators, but it may be made so light that the shearing strength of the thread will not be of much importance.

VICE-PRESIDENT SHELDON:—If there is no further discussion, we will proceed to the next paper. Do you care to make any closing remarks, Mr. Mershon?

MR. MERSHON:—There was a further remark made by Mr. Gerry to the effect that it is too early to adopt a standard pin. I think if we adopted a standard and changed it from year to year, we should not be any worse off than we are now, when we have no standard. There are as many standards as there are manufacturers of pins and designers of pole lines. The only way now to get a pin to fit an insulator is to send the insulator to the pin manufacturer and in that way have the pins made so that they will fit. If you buy a pin from one manufacturer and the insulator from another, they may fit, or they may not fit.

VICE-PRESIDENT SHELDON:—We will now proceed to the discussion of the paper by Mr. F. O. Blackwell on "The Testing of Insulators." As Mr. Blackwell is not present and has not delegated any one to present his paper, I will call upon Mr. Mershon to present the introduction.

MR. MERSHON:—If there is no objection, I will pursue the same course in regard to Mr. Blackwell's introduction as with

my own. I will omit reading his introduction and read the contributions to it. I think they take up most of the main points and will serve as a basis for the discussion this evening. The first contribution is by Mr. M. H. Gerry, Jr. It is as follows:

MR. M. H. GERRY, JR.—Mr. Blackwell has ably discussed a number of important matters in connection with the testing of high-voltage insulators. There are, however, a number of additional points which have not been touched upon.

Insulators are tested for two purposes: first, to determine the design, shape, material and dimensions best suited for a given voltage and set of conditions; secondly, insulators are tested as a matter of routine, to determine whether manufacturers have complied with specifications regarding material and workmanship.

There can be no complete set of tests to cover the first purpose, as it is not only a matter of experiment, but of skill and judgment in properly interpreting the results of many tests, in relation to service conditions. The testing of insulators for the second purpose is comparatively simple. For glass insulators it is usually sufficient to inspect them for physical defects, such as cracks, bubbles and incorrect dimensions. A certain percentage of the insulators should also be tested for proper annealing, and for mechanical strength. A chemical analysis of the glass of a few of the insulators is also desirable. Electrical tests of glass insulators are unnecessary, as the physical inspection will reveal everything that can be found by an electrical test. Porcelain insulators are more difficult to test than are glass insulators, on account of many defects being covered by the glaze. For very high voltages, porcelain insulators should be tested electrically, and should also be carefully inspected during the process of manufacture, and before the glaze is applied. This is especially desirable with insulators built up of several parts and cemented together by glaze or other material. Defects in insulators of this type are difficult to detect, even by electrical tests, unless they are pronounced.

Mr. Blackwell has indicated the proper method of making electrical tests of insulators. The puncture test mentioned by him, of twice the potential between wires is usually sufficient, but a higher test is desirable where the insulators are to be exposed to severe lightning strains.

MR. MERSHON:—I would like to speak in regard to the following sentence in the contribution of Mr. Gerry, which has just been read. "The puncture test mentioned by him (Mr. Blackwell), of twice the potential between wires, is usually sufficient, but a higher test is desirable where the insulators are to be exposed to severe lightning strains." I have never personally known or heard of a case of insulators having been punctured where the puncture could be laid to lightning. It seems to me the lightning would flash around most insulators rather than puncture them.

Then as to the question of the chemical analysis of glass insulators. I have never had any reason to think that the chemical composition of the glass made any difference in the behavior of glass insulators. I have made tests for difference in behavior due to composition on both insulators and tubes of glass, but never succeeded in finding any.

VICE-PRESIDENT SHELDON:—The subject is open for general discussion.

MR. P. M. LINCOLN:—I would take issue with Mr. Gerry, who made a statement that glass insulators did not need testing beyond visual inspection. I know of a certain line, the insulators of which were not given a voltage test, but were simply tapped with a mallet in order to eliminate, if possible, any which had undue internal strains. After the insulators were up and the normal voltage applied, quite a number of them broke down in actual service, which probably would not have occurred if they had been tested with voltage before being erected.

Another point, in regard to lightning, which Mr. Mershon speaks of—it is a fact that rain usually accompanies lightning storms, and that, of course, will give you a wet surface on the insulator. This wet surface is a very good conductor of the sudden surges which occur in lightning storms, so that lightning strains will be very apt to go over the surface rather than through the insulator. I do not think there is much danger of breaking down of an insulator from lightning strains, after a test of double normal potential has been applied.

VICE-PRESIDENT SHELDON:—Is there any more discussion?

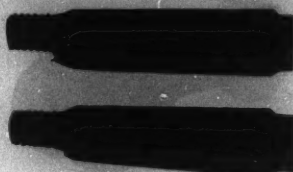
MR. W. N. SMITH:—While the subject is before the INSTITUTE, I think it would be quite interesting if any members present would state their preferences between porcelain and glass for high-tension insulators. It is a question that comes up every now and then, and no doubt there are members present who may have a very strong leaning toward one or the other material for high-tension transmission.

MR. MERSHON:—As between glass and porcelain, it seems to me about the only advantage, other things being equal, that porcelain has over glass for transmission work is that of mechanical strength. Sometimes it has that advantage and sometimes it has not. It is a fact, however, that in some forms of insulator—in some complex forms—it is possible to get the porcelain insulator cheaper than the glass one. I have found this true, to my surprise, in one or two cases. When the insulator is large, so that it takes the form of a very heavy central portion of glass, with long, thin petticoats, it seems to be almost impossible to make it of glass and have it symmetrical. The thinner portions cool first, and when the insulator is taken from the mold the weight of the outer portions distort the inner portion of the insulator, which is still hot. An advantage has also been claimed for porcelain over glass because of the lesser hygroscopic effects, but I think in most power transmissions the small amount of power necessary to dry up whatever moisture will get on the

surface of the insulator in that way would not be serious. As a matter of fact, in any measurement I have ever made, no difference could be detected between porcelain and glass in the matter of losses over their surfaces at high voltages.

Mr. T. W. SHOCK:—I had the pleasure of building a line this last year in the State of Pennsylvania, in which I used an insulator which tested for 75,000 volts. The ordinary pressure will be 24,000 volts—that gives a factor of safety of over two. I think I agree with Mr. Blackwell, that in testing insulators for a line of high pressure the testing pressure should be at least two and possibly three times the ordinary line pressure. My idea in adopting that style of insulator is due to the fact that it was built for a line on the Pacific coast, for 40,000 volts, and I adopted it to give me an extra factor of safety. I made the test at a pressure of 75,000 volts. I think the insulator will give us very good satisfaction.

Mr. F. N. WATERMAN:—Mr. Blackwell's reference to testing a double insulator—an insulator primarily of two parts—



Broken 10 $\frac{1}{2}$ " pins (Stem.) Total Length, 15 $\frac{1}{2}$ " Showing How Pins Split.

requiring that each part should be separately tested, seems to me practically to bar out double insulators and does not seem to be logically founded. He says, "if it is to be tested for 100,000 volts and is made in two parts, each part might, for instance, be tested with 70,000 volts. The object of this is to have the weak parts rejected before they are assembled." The objection to that, from a practical standpoint of course, is evident; but there is a further objection, not so evident, and that is, as I understand the porcelain people, in the baking or vitrifying of the two parts it is not desirable to take the entire shrinkage out on the first heat. Consequently, if the insulators are to be tested before being filled with glaze and re-vitrified, they are not tested at all in their final condition. Furthermore, I think it is illogical for the reason that it is a well-known fact that if we get porcelain in thin parts, we have a very much more than equal chance of getting sound porcelain. That is, if the same insulators were made in one part they would only have our final test, while the double insulator with much greater initial

chance of being sound is required to be tested twice. The test peculiarly required by the double insulator is the mechanical test, and as far as my observation goes—I have tested a good many of them—if they are substantially free from large air spaces, they will stand up under the final electrical test. It seems to me that the requirement of a double test is unfair and unnecessary.

MR. THOMAS:—Mr. Gerry, Mr. Lincoln and Mr. Mershon have referred to one point in the testing of glass insulators that deserves a good deal more consideration, and that is the initial strains left in the manufacture and annealing of the glass. The breakage of glass insulators on the line during service may more often be due to too much sun on one side of a poorly annealed insulator than to electrical strain. I do not know of any test which has been suggested to determine whether glass has been properly annealed or not, but I do not doubt that some test could be gotten up, and I make the suggestion to the committee that they consider this point carefully. A successful test would save a great deal of trouble in high-tension lines after the insulators



Iron-Pin Insulator.

are installed. There is one rather old point which should be mentioned in the testing of porcelain insulators—not only should they be tested with salt water, but the regulator should soak a certain definite time; the Standardization Committee might determine how long.

MR. C. C. CHESNEY:—A glass insulator, if it is not properly and uniformly annealed, has unequal strains in the different parts of the glass. I have known a number of such insulators after a cool night to break when the sun struck them in the morning. The side towards the sun cracks off. Aside from this feature, I believe a glass insulator will give as good satisfaction as a porcelain one.

MR. MERSHON:—I cannot entirely agree with the author in regard to the use of one transformer for testing purposes. A series of transformers need not have a bad regulation or seriously distort the wave form, and such a testing set has a very great advantage that a transformer break-down is much less serious than in the case of a single testing transformer. The knowledge

of this fact gives one more confidence in testing, especially in experimental testing. For very accurate results in any case a step-down voltmeter transformer is desirable.

Neither can I agree that insulators should necessarily be tested on iron pins. As I have stated before, an iron pin is likely to be the means of putting upon the insulator a mechanical stress all out of proportion to any which it would meet in practice if installed upon a wooden pin. For instance, if the insulator be screwed down tight upon a metal pin there will result stresses in the head tending to force the top of it off either at one of the threads or at the bottom of the pin-hole, or tending to burst the head. In either case there is a resulting mechanical strain in the substance of the insulator inviting puncture perpendicular to the lines of stress. An insulator that will stand up well under a salt water test, will often break down quickly when tested on a metal pin. While I do not believe in depending upon the wooden pin for insulation, I see no good reason for condemning it in general where there will be no

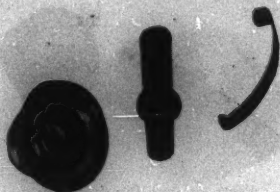


Parts of Iron-Pin Insulator.

trouble from burning. The author says that wooden pins burn off eventually unless the insulator be good enough to be used with an iron pin. If the insulator be good enough to prevent burning of the wooden pin, why not use the wooden pin unless there be some mechanical requirement which it cannot meet.

I agree thoroughly that any new type of insulators should be given a rain test; that is, a voltage test while water is being sprayed upon the insulator in imitation of rain. If a wooden pin is used in this test, it should be covered with tin foil from a point inside the petticoat nearest the pin to a point two or three inches below. The voltage should be applied between the foil and a wire around the neck of the insulator, or, preferably, between the foil and a piece of wire representing the line wire and tied to the insulator as it will be in practice. The recommendations of the Introduction as regards the angle at which water should be sprayed; is all right, if this angle be uniformly adopted in testing; but some definite angle should be adopted, as the angle makes considerable difference in the voltage at which the current will arc from the line wire to the pin. The recommendations in

regard to the spray are not, however, so specific as could be desired. The amount of water sprayed, as well as the angle, makes a difference in the arcing voltage. Some time ago I endeavored to obtain from the United States Weather Bureau information as to the most violent precipitation on record in this country. The record sent me showed the most violent down-pour as being about .8 of an inch in five minutes. The maximum rate of downpours during that time may, of course, have been greater than this. It has been my practice to endeavor to adjust the spray for a precipitation of one inch in five minutes. This can be most conveniently done by placing under the insulator a suitable pan and collecting in it the water for five minutes. Care must be taken that in placing the pan it does not receive water from any part of the cross-arm other than that just over it. The question of the method of obtaining the spray is one which it is well to consider. It is no easy thing properly to adjust the spray from an ordinary garden spray nozzle or rose spray and it is no wonder that uniform results are not



Parts of Iron-Pin Insulator.

easily obtainable. It is desirable, if possible, to have some special form of spray-nozzle which will give a uniformly distributed spray. This might perhaps be in the form of a very large rose spray of a foot or more in diameter.

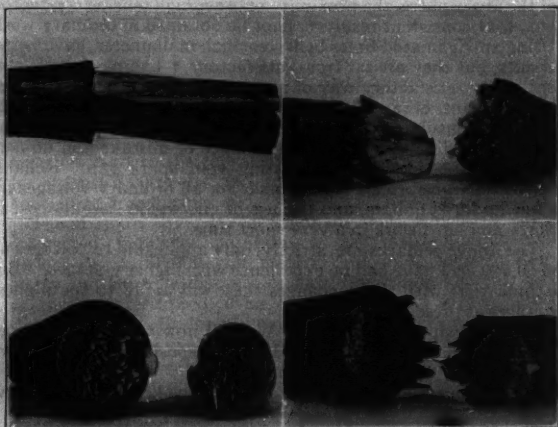
It is desirable that if possible we arrive at some definite decision this evening on the points mentioned in regard to the methods of testing insulators, so that recommendations can be made on this subject to the Standardization Committee.

VICE-PRESIDENT SHELDON:—There is a written contribution on this subject from Mr. W. L. Waters, of Milwaukee, Wis.

MR. W. L. WATERS:—The form of potential wave given by modern alternators differs very little from a sine wave. The worst case commonly met with is that of a three-phase alternator wound for high voltages. These machines have usually three slots per pole, and the wave form shows pronounced harmonics of five and seven times the fundamental frequency, but the effect of this distortion on break-down voltage of an insulator is inappreciable. The only commercial machines that have wave

forms which would affect the accuracy of the results to any extent are the old single-phase revolving armature machines with projecting poles on the armature, which show a pronounced third harmonic. But these machines are seldom met with now. The charging current in a test on insulators or an overhead line generally conforms more or less to the potential wave form of the alternator, and whether the current is lagging or leading the distorting effect on the wave form is slight, and with all ordinary excitation and loads on the alternator the effect on the insulator test will be inappreciable.

Generally speaking, an insulator will stand momentarily a voltage strain which, if continued long enough, will break it down:



1. Pin Split in Shank and Broken at Cross-Arm.
2. Pin Broken at Upper Part of Shank at Cross-Arm.
3. Pin Broken at Upper Part of Shank at Cross-Arm.
4. Pin Broken at Upper Part of Shank at Cross-Arm.

and this time effect is most marked in solid insulators. A gas such as air does not show this. When air is going to break down under a given strain, it will do so almost as soon as it is applied, except where the insulation of the air is subsequently weakened by a violent brush discharge. Solids show this effect to the greatest extent, and liquids such as oil to a lesser extent. And I have found that in insulating materials where this effect is most marked, differences in wave form have little effect upon the break-down voltage; it seems to be the mean voltage or possibly the r.m.s. voltage which decides the break-down. In air the wave form has quite an appreciable effect, and the difference between a peaked wave and a flat wave may be as much as

20 per cent. of the sparking distance. Porcelain insulators show very markedly this time effect; they will stand a much higher potential if applied instantaneously than they will if applied continuously, and as far as can be seen from the experiments I have made, they appear to conform with the rule mentioned above, and are practically unaffected by wave form. The sparking distance in air, on the other hand, being considerably affected by wave form, shows at once the unsuitableness of using a spark gap as a voltmeter if there is any doubt about the wave form. And I have found that unless it was in the hands of a very careful and experienced man, a spark gap was not of very much use in accurate work. Using needles as electrodes, the voltage seems to vary so much with the condition of the points, the state of the atmosphere, the proximity of other high tension conductors etc., that consistent results cannot be obtained in ordinary work. Using amalgamated brass balls, one inch in diameter, gave better results, but they are far from satisfactory. I think there is only one really satisfactory way of measuring high voltages, and that is by means of a voltmeter transformer connected straight across the insulator being tested. This method is accurate and is direct reading, and there is no chance of mistake and no continual trouble fixing and adjusting your spark gap. Reliable voltmeter transformers can be made for all ordinary voltages for a few hundred dollars, and the use of one would save its cost in worry and hard work in a very short time.

The above remarks are, strictly, only applicable to voltages up to 50,000, as I have had no experience with higher voltages. But I think that with slight changes they will apply to the highest voltages at present in use.

VICE-PRESIDENT SHELDON:—We will now take up the paper by Mr. P. M. Lincoln, entitled, "Transposition and Relative Location of Power and Telephone Wires."

Mr. Lincoln read his introduction (see page 427), and the following contribution by Mr. M. H. Gerry, Jr.

MR. M. H. GERRY, JR.—Mr. Lincoln has discussed the most important requirements of telephone construction in connection with high-tension transmission lines. There is no especial difficulty in installing a successful telephone circuit which will give satisfactory service and reasonable safety in operation on a pole line carrying from 50,000 to 60,000 volts.

Mr. Lincoln has mentioned the principal requisites of successful design, which are a proper adjustment of the capacity, a maintenance of high insulation from ground, and a complete transposition of the telephone wires in reference to each other, to the power circuit and to the ground. In addition, might be added the use of certain safety devices, which reduce the danger in handling telephones connected with circuits on high tension pole lines.

In regard to transpositions: Mr. Lincoln advocates the transposition of the telephone wires only, but it is desirable also to transpose the main power circuits, in order to reduce to a mini-

mum the voltage to ground on the telephone circuits. But few transpositions of the power circuit are required, and the service as a rule is materially improved thereby. Where there is considerable lightning, arresters should be installed on the telephone circuits of a design similar to those used on lighting circuits. The ordinary telephone lightning arrester is an undesirable and unsafe piece of apparatus for this purpose. Fig. No. 7 is a sketch of a telephone arrangement devised by the writer, which will give excellent results in service. Especial attention is called to the short gaps across the line, to the location of the lightning

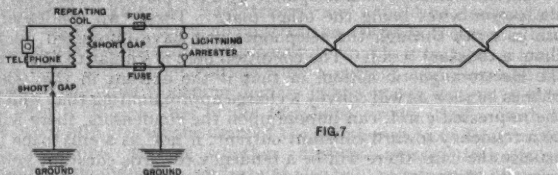


FIG. 7

arresters, and to the repeating coils, which should be insulated for at least 5,000 volts, and may be immersed in small glass jars containing transformer oil.

The Missouri River Power Company, with which the writer is connected, regularly maintains a very satisfactory telephone service on its 50,000 volt transmission lines between Canyon Ferry and Butte, a distance of sixty-four miles, and this service is rarely interrupted, even during the most severe lightning disturbances. Under normal conditions, there is no potential on this telephone line, and only the slightest hum can be detected.

MR. LINCOLN:—There is one point upon which possibly my discussion is not quite clear, and that is in regard to the transposition of the power circuits. I have stated that it is not of very great importance. My reason possibly is not very clear in the paper, and it is this—a telephone line ought to be so made that it will at all times operate, even if one leg of the power line is dead grounded. If it is made to operate under these conditions it will operate under the normal conditions of an untransposed power line, because the normal static potential induced in the telephone line by an untransposed power line is vastly less than that which will be induced in the telephone line by grounding the power line; so that if the telephone line is installed so as to run under grounded conditions, that is, with the power line grounded, it will certainly run with an untransposed power line.

VICE-PRESIDENT SHELDON:—The subject is now open for general discussion.

MR. RALPH D. MERSHON:—The truth of the observations of paragraph (6) is not clearly evident to me. The relation between the telephone circuit and the power circuit is, as stated in paragraph (4) such that in their electromagnetic relations they con-

stitute a transformer—an air-core transformer and one having very poor regulation. This transformer has in its primary—the power wires—a current unaffected in value by any current in the telephone wires and which may therefore for any given condition of power load be considered as a constant current. If the telephones took any appreciable amount of current, an amount comparable to the power current, we should have a tendency toward constant current in the telephones. If, as is the case, the telephones take a current very much less than the power current, we will have a tendency for constant voltage.

Electrostatically, each telephone wire is a plate of a condenser, the power wires being the other plate. These two condensers are in series through the telephones and have impressed upon them a constant e.m.f. The condition here is similar to that for the electromagnetic action, in that if the current in the telephones be such as will convey a charge approximating that which the impressed e.m.f. can impose upon the condensers, there will be a tendency toward constant current; if not, as seems to me is usually the case, there will be a tendency towards constant voltage. In short, it seems to me that the conditions are about the same in the case of the electromagnetic and electrostatic disturbances. This is on the assumption that the reactance of the telephone is low relative to its resistance. If this is not the case, and the reactance is comparable to the condensance concerned in the telephone circuit, then the current conditions may be almost anything, depending upon the relations between these two quantities. Further, if by telephones of various resistances it is meant to designate telephones of various numbers of turns in the transmitter, then it seems to me the statement in regard to the disturbing ampere-turns is incorrect. The resistance of a coil varies as the square of the number of turns (assuming the same space available in each case for copper). The ampere-turns on constant e.m.f. vary, therefore, inversely as the square root of the resistance. It would seem, therefore, that if, as stated above, the electromagnetic and electrostatic effects are constant potential in their nature, telephones should be wound for as high resistance as possible. This seems reasonable, as it is equivalent to saying that the telephonic e.m.f. should be kept as high as possible, which in turn is equivalent to saying that the disturbing e.m.f. should be as small a percentage of the telephonic e.m.f. as possible. In order to solve some of these questions, it is necessary to know the current and e.m.f. of telephones. I have no such data and have not been able so far to obtain them.

(7) It does not seem as though the objection given for the use of the series telephone were a valid one, since one ought not to introduce a telephone at *s*, Fig. 2, any more than one would connect a bridging telephone at this point. In other words, telephones, whether series or shunt instruments, should be connected at even transpositions in order to obtain the best results.

(14) It is not quite clear to me why the series telephone should

not be a satisfactory instrument. As has already been stated, the reason mentioned in (7) seems hardly a valid one for condemning it.

(15) There is another method of accomplishing this desired end of having the telephone lines as nearly as possible at the same potential as the earth, which seems preferable for the use of a grounded wire; first, on the score of simplicity, and secondly, because it may also be a means of protection against loss of life or fire. This method is that of using autotransformers connected across the telephone line at a number of points, preferably at each of the telephone stations, each having its middle point connected to ground. Each transformer should be designed so as to take a very small amount of the telephonic current, but should have wires sufficiently heavy to enable it to take, in case of a cross with a high voltage wire, a current heavy enough to operate the circuit opening devices in the power station or else to blow a suitable fuse in the telephone circuit itself. Such a device would protect the users of the telephones from disagreeable or dangerous shocks, whether due to crosses, leakage or electrostatic induction, and would also help to minimize disturbances due to grounds, etc.

MR. P. H. THOMAS:—I think that the subject of telephones on long distance power transmission lines is perhaps the most important subject we have to-night. Mr. Lincoln has given a very good statement of the fundamental principles underlying the difficulties that have been found in many cases. By exchanging experiences and making suggestions, we can probably base on these fundamental principles improved methods by which the present service can be very much benefitted. As Mr. Lincoln concludes, I think there is no doubt that the trouble is chiefly due to the electrostatic induction from the normal voltage which tends to raise both telephone wires above the earth, either positively or negatively. There will also be a momentary disturbance whenever we have a charge of a lightning arrester, or any static discharge, in the neighborhood, but that will not give much trouble as regards clearness of communication, because it is over quickly. The transposition of the transmission line is, I think, an important point practically in high-voltage transmission. As Mr. Lincoln states, a telephone circuit *should* be built to work under all conditions; for instance, when one line is dead grounded. But if it is impossible to make it work at such times, and if you can make it work smoothly when not grounded by transposing the power line, you had better transpose it, and that is the actual condition of practice.

Assuming both telephone wires are going to reach high potential above the earth, there is only one thing to do to get service at all times, and that is to eliminate the baneful effects of the high potential.

I will make a suggestion for accomplishing this purpose, which may not have much practical value, but should be worth trying.

I hope that some of the engineers who have opportunities for experimenting at hand will try it for their own and the general good. For instance, it is possible we may be able to insulate the telephone wires, perhaps for 30,000 or 40,000 volts in an extreme case, and at the end of the line put the primary of a transformer and connect the telephone to the secondary, thus making very high insulation between the primary and secondary. By this means it would be possible to protect the operator, and since static disturbances do not induce potential between the two wires, it should not disturb the speech. The same result may possibly be accomplished with condensers, by connecting two condensers in series between the two pair of wires and putting the telephone in between the condensers, not connected with the line. In this case it will probably be necessary to put a choke-coil between the condensers and ground its middle point. The charging current of the condensers will be neutralized by going through the two halves of the coil in opposite directions and a telephone winding could be taken from the same core.

Mr. Lincoln suggested carrying ground wires in close proximity to the telephone wires. This should help much and would be a good method to try, but it would probably be necessary to use insulated wire for the telephone circuit, otherwise there would be trouble from repeated grounding. One method, which would be effective, but perhaps not practicable, would be to use for each side of the telephone wire a twisted pair; one wire of the pair for the telephone circuit and the other of the pair grounded. This method would make a large capacity between the telephone wire and ground, but would not actually ground the telephone wire itself.

There is another interesting possibility for those who like to speculate. Can we not use the power transmission wires themselves for sending signals? If not for telephoning, at least for general signaling. For instance, as a suggestion, we might connect a high resistance between each wire and a common point, and connect this point to ground, and similarly at the other end; then put a high frequency generator between the ground and the common connection at one end of the line, and some kind of receiving apparatus in the other. The high frequency would prevent the transformers from taking too much current, and you might be able to signal when power was on the lines. The same thing might be done with condensers or choke-coils. The advantage of using all the wires in parallel for signaling is that if you have three or four wires burnt off, there might yet be one wire you could signal through.

Another point is, it would be possible to make temporary arrangements for signaling in times of shut-down, until the power comes. That is, when voltages go off, it would be possible to use the dead wires to make arrangements to start up again. Things are in a critical state when the power is off, and the telephone lines down, and such a system of signaling might easily be arranged.

Another thing is very important, and that is the protection of the man using the telephone. One or two fatal accidents have recently occurred to operators on the telephone circuits. They should be either insulated in a booth, or the circuits should be dead grounded, or protected through an air gap small enough to be safe for the operators.

In regard to Mr. Lincoln's statement that telephone wires may reach as high a voltage as 20,000 volts. It occurs to me that as perhaps his statement is based on theoretical considerations, I can emphasize it by stating that I have seen this voltage in fact, in Mr. Gerry's plant. I have seen sparks from telephone line to ground which were something like half an inch long, indicating perhaps 20,000 volts, perhaps higher than that. The possibility which Mr. Lincoln describes is not at all imaginary; it is very real.

MR. C. E. SKINNER:—I wish to emphasize the last point made by Mr. Thomas, that is, the protection of the workman. The insulation of the instruments in the building has been mentioned by Mr. Lincoln. The insulation of the workman is even more important, and it is not difficult to make arrangements so that he will be well enough insulated, so that even a cross between a high potential line and a telephone line will not do serious harm. It is usually painful to receive a shock of this character, but not particularly dangerous. It has been my observation that men handling telephones on high tension transmission lines, soon learn to be very cautious and are usually compelled to watch the surrounding material, walls, etc., when telephoning. This could be easily avoided by proper arrangements, so that the man need not touch anything which would connect him to the ground.

MR. C. O. MAILLOUX:—I would like to mention a phenomenon in connection with the charging of lines which, while not exactly within the scope of this paper, is still interesting, especially as it is a phenomenon which has puzzled me and which has puzzled others to whom I have mentioned it. I have observed the fact that the transmission line will become spontaneously charged electrostatically without being connected to any generating machinery. About a year ago, in Arizona, we repeatedly observed that the three wires of a 25 or 26 mile line would become charged spontaneously to a considerable potential under various atmospheric conditions. In Phenix, Ariz., at this time of the year, the weather is very much the same as it would be here in June of July, except that there is no rain. The weather is usually very pleasant, quite warm in the day time—one can wear summer clothes—and it cools but very little in the evening. There are occasionally slight winds, especially over the deserts, over a portion of which the line runs. I have repeatedly observed, but during the day time only, or until early evening, that the three lines became charged electrostatically. They could be discharged by making a connection to earth, but if left

alone they would soon charge again (in 10 to 15 seconds). The three wires would always charge at approximately the same potential with respect to earth, but this potential varied, as might be expected. It depended on the weather apparently, and varied, of course, with the length of time allowed for recharging. On one occasion, when there was a heavy wind preceding a rain, the potential was so high that we got sparks an inch and a half between the lines and the ground, through spark gaps. I have repeatedly observed cases where the spark was $1/16$ to $1/4$ of an inch between sparking points. There were no indications of lightning or storm. There have been cases where the phenomenon was observed when it was raining, (at the distant end, which is near the mountains, where it rains occasionally), or shortly after it had rained; but the phenomenon was never so marked at such times; it was repeatedly observed when there was no indication of rain whatsoever, the sun shining brightly, but there was then always some wind or slight breeze somewhere along the line. My own theory was that the charge was either caused or translated by the wind, and taken up by the wire surfaces acting as condensers. I have mentioned the matter to several physicists, but my theory was rejected, as moisture in the air is considered indispensable, and it was lacking in this case. I have not succeeded in getting any satisfactory explanation. I hope there is someone here this evening who may be able to give it.

Another interesting phenomenon which I have observed in the same climate is the fact that the lightning arrester, which is located at each end of the line, has generally a tendency to frying discharge, which is more pronounced between the lightning arrester gap of one line than of the others. It was not always the same line, but changed from one line to another. I could not determine with the facilities we had what that was due to, but I was tempted to ascribe it to some sort of electrostatic action. The three line wires were systematically transposed in building this line, so as to bring an equal length of each of the three wires in the same relation with the surface of the ground.

MR. LINCOLN:—The point has been brought up about the use of series telephone versus the bridge telephone. I know by bitter experience that the series telephone does not give very good satisfaction. I once had charge of a line on the poles of which was run a telephone line, and on that telephone line we had about fifty series 'phones scattered along over twenty-five miles, about half a mile apart. We were never able to get successful service from that system. I ascribed most of the difficulty to the fact that the talking current had to go through so many loose contacts, so many jacks, and it is almost impossible to keep so many contacts in good shape. With the bridge 'phone it is necessary for the speaking current to go through only one pair of loose contacts or jacks at each 'phone. That constitutes one great advantage of the bridge over the series telephone.

The suggestion has been made that the potential between telephone wires and ground can be reduced by introducing between them autotransformers or condensers or resistances and connecting the middle points of these autotransformers, etc., to ground.

The objection to that method, it occurs to me, is that it takes off the charging current at concentrated points. The current is induced in these telephone wires as a distributed effect, distributed along the whole length; and if you try to take it off at bunched points, there will be a flow of current in the telephone wires which will introduce an e.m.f. and probably make disturbance in the telephone. The remedy which I proposed is to run a ground wire along the whole length of the telephone wire, producing a distributed capacity which will take care of the distributed induced effect most efficiently.

MR. MERSHON:—With regard to the use of condensers on telephone lines, it seems to me we want to keep the capacity of the telephone lines as low as possible to get good operation of the telephone.

If any one wanted to signal with the power lines, it would be better to signal from neutral to ground, and receive messages at the corresponding place at the end of the line.

I do not think the objection Mr. Lincoln makes, relative to the use of autotransformers on telephone lines, that the current would be drawn off at certain points, whereas it is introduced uniformly along the telephone line, would hold, as the current is flowing in the same direction in both telephone wires, and the effects of the two currents will neutralize each other so far as the telephones are concerned.

VICE-PRESIDENT SHELDON:—We will now proceed to the consideration of the paper on "Burning of Wooden Pins on High Tension Transmission Lines," by Mr. C. C. Chesney.

Mr. Chesney presented his paper (see page 435) and read the following contribution by Mr. M. H. Gerry, Jr.

MR. M. H. GERRY, JR.:—On a certain number of high-tension transmission lines there has been burning of the wooden pins. On other transmission lines of high voltage, there has been no such burning. Where burning has occurred, it has been due to leakage of current from the surface of the insulators, coupled with resistance conditions in the pin, such that sufficient heat was developed to char the wood.

When thoroughly dry, wood is one of the best of insulating materials, and one of the poorest when containing sap or moisture. The greatest objection to it is its unreliability, due to the difficulty of removing the last traces of sap or moisture. A thoroughly dry wooden pin, fifteen inches in length, will stand indefinitely 100,000 volts pressure, while a green pin of the same length, containing sap, will break down very quickly under 1,000 volts pressure. Paraffining the pins on the outside, or coating with asphaltum or linseed oil, is of no value. If the pins

are thoroughly dry, the material in which they are dipped can be made to impregnate the entire body of the wood, thus producing a pin of high insulation. Such a pin is of value, as it reduces the static strains on the insulator and decreases the amount of leakage to ground.

In order to prevent burning of pins, they should have either very high or very low resistance. With insulators having a large amount of surface leakage, such as those illustrated by Mr. Chesney, an iron pin is perhaps the only solution of the difficulty.

There is nothing especially mysterious about the burning of wooden pins on high-tension lines, as it is merely a matter of total resistance to ground and the relative resistances of the insulators, pins, cross-arms and poles. Wherever burning occurs, it can be remedied by altering the design, material or dimensions of the insulators and improving the quality of the pins.

MR. H. W. BUCK:—Referring to the point which Mr. Chesney spoke of in regard to the so-called "digesting" of pins, I have seen many pins taken from the Niagara-Buffalo transmission line where such disintegration had occurred, the top of the pins having crumbled into a white powder. We have recently had some of this powder analyzed by a chemist and it was found to be a nitrate salt. This would look as if nitric acid had been formed in the presence of a static discharge inside of the insulator by the well-known atmospheric reaction and had attacked the wood, forming the nitrogen salt in combination with the vegetable matter of the pin.

In this connection I would like to say that about six months ago we built an experimental single phase line at Niagara, about two miles in length, and operated it continuously for nearly four months at approximately 75,000 volts. The conductors of this line were galvanized iron wire, tied to the insulators with copper tie wires. At the end of the experimental run, the galvanized iron wire had turned black to a considerable depth throughout its length. The copper tie wires had also been attacked, though not so much as the iron. This surface disintegration was not due to general atmospheric influence, for iron wire in the same place but not charged electrically retained its original bright condition. I believe that this action is also due in some way to the influence of nitric acid formed by the brush discharge around the conductor. It indicates that some trouble may be experienced at such excessively high voltages where static discharge from the line is active. This discharge probably causes a combination of the oxygen and nitrogen of the air which, with the moisture of the atmosphere, forms a film of dilute nitric acid surrounding and attacking the metallic conductor.

MR. LINCOLN:—Mention has been made by Mr. Chesney and in the communication of Mr. Gerry as to the treatment of pins. I think the treatment of pins should be with a view to making them durable rather than making them good insulators. The pins should not be relied upon as a part of the insulation. As

long as they are dry and as long as the weather is perfectly dry, they may be most perfect insulators, but as soon as rain comes, and the pins are wet on the surface even, they become practically useless as insulators and the entire insulation strain on the line falls on the insulators. We should treat the pins, therefore, with a view to preserving them rather than making insulators of them.

MR. MERSHON:—It does not seem that, as Mr. Lincoln stated a few minutes ago, when the arms and pins get wet, the insulation is all in the insulators; because if this were the case, I do not quite see how the sides of the pins next to the sea should be burned, and the sides away from the sea should not be burned. It seems to me it would be the other way. If the insulator controls the current, the lower the resistance of the pin, the less burning, and when the pin is charred all over there should be less heat generated on the surface, and consequently less tendency to burn. But if the pin does to some extent control the current, the lower the resistance the greater the current over the surface, and the more likely it is to burn, especially over any part of it which has had its resistance lowered.

The path of the leakage current from wire to wire of a power transmission line may be considered as a high resistance electric circuit, derived from a constant potential source. The total resistance of this derived circuit is the series of the resistance of the three elements, insulators, pins and cross-arms. The resistance of each of these elements is that resulting from two resistances in multiple; namely, the resistance of the element through its substance and the resistance over its surface. The substance resistance of all the elements is usually high, so high in a well constructed line that it need not be considered.

The surface resistance of the three elements may or may not be high, depending upon the surface conditions as regards moisture, dust, dirt or other deposits. Suppose the surface conditions of all the elements is such as to allow considerable leakage. No harm will result to the insulator unless the leakage becomes great enough to start an arc. This is not the case, however, with the cross-arms and pins. The leakage over their surfaces if great enough will char all the surface over which it passes. Pins are more likely to char than cross-arms, since their surface is less and their surface resistance, therefore, higher than the cross-arms; the result being, for a given leakage current, more loss per unit area of pin surface than of cross-arm surface. Any protected portion of the pin is especially liable to charring. For, if the cross-arms and pins have their exposed surfaces pretty thoroughly wet or dirty, so that the current passes over them with little resistance, the wet or dirty portions may be little affected; but if in the course of its path the current encounters any small portion of the pin which is not wet or which for any reason has a higher resistance per unit of length, the wood may be charred at this point. Now, this is what happens when the pins burn. The insulator, the lower part of the pin, and the cross-arm have their

surface resistance lowered by moisture or otherwise, but the upper part of the pin being protected by the insulator does not have its surface resistance so much decreased; the consequence is burning of the protected surface. In some cases the inner surface of the insulator next the pin and the pin itself are so well protected by the insulator that the current, instead of leaking over the surface of the insulator until it reaches a point where the insulator and pin are in contact, jumps in a brush-discharge from the edge of the petticoat to the pin rather than follow the higher resistance of the protected surface. As a result, the pin is burnt at the point where the brush discharge strikes it instead of at or near the thread. There are apparent three possible remedies for the trouble due to charring pins:

1. Make the design and size of the insulator such that for all conditions its surface resistance will be so high as to control the leakage and keep it below a point which can harm the pin.

2. Make the pins fireproof, but non-conducting.

3. Make the pins conducting.

The remedy recommended in the introduction to this discussion is (3). It is recommended that an iron pin be used. This certainly would do away with the trouble of charring pins, but whether or not it will introduce other and more serious trouble remains to be seen. It seems to me there is a very likely chance of trouble from the use of iron pins, due to the unyielding character of both iron and porcelain or glass and their widely different coefficients of expansion. Insulating material under mechanical stress will generally break down under a lower voltage than when not strained. An insulator on an iron pin might, when installed, be put under a considerable mechanical stress or one which when first installed has comparatively little stress upon it may, due to changes of temperature, be much strained; the result in either case, is increased liability to puncture.

The endeavor may be made to get around this trouble by using a wooden thread upon the iron pins, but as is shown by one of the cuts in the introduction, the charring trouble may still remain if this course is adopted. If a wooden cross-arm is used with the iron pin, the seat of the charring trouble may be transferred to the cross-arm unless the pins be connected by a conductor. It would seem better to adopt the first remedy and make the design of the insulator such as to protect the pins.

MR. DE MURALT:—It may possibly interest you to know that while the general practice in America is evidently to use wooden pins, in Europe it is just the opposite. Practically all the high potential installations use iron pins, and more than that, while here very often the whole pole is treated with as little iron as possible. In Europe there are quite frequently poles constructed entirely of iron, with iron cross-arms and iron pins, and the only insulation relied upon is the insulation proper. I believe this does away with the burning of pins, cross-arms and poles. I do not think there is very much difficulty in the way of avoiding

mechanical strains, which have been alluded to several times to-night, with regard to fixing the insulator in the pin. One way to get around that is to fix the pin into the insulator by means of a cement which will take up any such strain, and in a great many installations that I know of a cement made of a mixture of litharge and glycerine has been used with, as far as I know, very good results. It seems to me that it is a very fair scheme thus to lay the entire insulation into the insulator, and then let the rest of the pole take care of itself. I know of one installation, where they are operating at 26,000 volts, using American glass insulators and iron pins and iron poles; and of another one which is using 25,000 volts, and has porcelain insulators, with iron pins on wooden poles part of the way, and iron pins in walls and on any kind of a support on the other portion of the road. Neither of these installations has not given any trouble whatever and they are amongst some of the best high-voltage installations in Europe.

MR. PHILIP TORCHIO:—I want to suggest an explanation of the burning of the wood between the iron pin and the porcelain base in the Locke insulator shown in Fig. 3 of Mr. Chesney's paper. I wish to call attention to the fact that, if two plates are maintained at a certain difference of potential, acting as condensers and spaced at such a distance that there will be no discharge between the plates, but set near the limit at which the discharge would begin and then there is inserted in the middle a plate of vulcanized rubber, which has a higher dielectric resistance than air, right away the discharges take place between the plates. Now, that is contrary to what might have been expected. The explanation is that before the insertion of the vulcanized rubber plate the fall of potential between the two plates of the condenser is a uniform straight line, but when we introduce the vulcanized rubber plate we alter the conditions, as we have then three condensers in series, which will distribute the total fall of e.m.f. in inverse ratio to their capacities. Therefore, this plate of vulcanized rubber acting as a condenser with a larger capacity than the same amount of air which it displaces, will be charged at a smaller fall of e.m.f. between its faces than existed before, and the e.m.f. between the outer condensers will be increased and then the discharge begins. Now, it seems to me that in the Locke insulator, with double porcelain petticoats and an oak thread between iron pin and porcelain, there are present the conditions of several condensers in series which might give rise to a lack of uniformity in the distribution of e.m.f. between line wire and iron pin and cause the charring of the wood at the base of the insulator.

MR. C. E. SKINNER:—I understand that the pins used on one transmission line were selected with the utmost care, and were most carefully treated, and that they have had practically no trouble whatever in more than a year's run with a potential of over 50,000 volts. These pins are protected from the weather

by glass sleeves. We should keep in mind that this is in a different climate from many other installations, and that a cure for these troubles in one climate may not be a cure in other climates.

MR. W. N. SMITH:—In the matter of wood and iron pins, it seems to me that along with various other elements the question of cost will govern. Iron poles in this country at this time cost anywhere from \$30 up, and a wooden pole of suitable size runs from perhaps \$7 to \$20, according to size and where it can be obtained. The size of cross-arms may be governed to some extent by the size selected for the butt of the pin. If you determine first on the size of the shank of the pin that enters into the cross-arm, that in a measure determines the thickness of the cross-arm, if of wood and larger than usual. That may mean quite an additional percentage to the number of feet of lumber to be bought to provide cross-arms for a long pole line. Lumber is higher than it used to be, so that there are considerations, commercial as well as technical, that these various elements of design all enter into. The cost of selecting some particular pin because it looks a little better may thus run into some thousands of dollars on a long pole line.

VICE-PRESIDENT SHELDON:—We will now give Mr. Chesney an opportunity to close the discussion on his paper.

MR. CHESNEY:—I was particularly interested in Mr. Buck's information concerning the cause of the "digesting" of the pin. This has bothered me on a number of transmission lines. I attributed this trouble to the formation of ozone. If it is due to the formation of nitric acid, I am glad to know it. As far as I know, on the particular line on which the Locke iron pins with wooden threads were used, the burning was not serious. The thread was punctured at one point but was in no other way injured. In order to relieve the mechanical strain between the iron pin and the insulator, I think it is quite possible to use a lead thread. Litharge and glycerine have been used to some extent in this country to cement iron pins in porcelain insulators, but lately Portland cement has been used with quite as good results. I understand that one of the largest new transmission lines in Mexico is to be built with iron pins and porcelain insulators. The pins will be cemented in the insulators with Portland cement. Instead of iron poles, iron towers will be used, placed 400 or 500 feet apart.

VICE-PRESIDENT SHELDON:—We will now close the meeting by having a paper from Professor W. S. Franklin, entitled, "Model Showing Distribution of Electromotive Force and Current along a Single Phase Alternating Current Transmission Line." (See page 443.)

PROFESSOR FRANKLIN:—I feel like apologizing to you for taking up your time at this late hour, so I will not take the time to read the statement given in the paper, but will simply exhibit the model itself.

(Prof. Franklin then exhibited and briefly described the model.)

The meeting then adjourned.

A NOTE ON LINE INSULATION FOR HIGH VOLTAGE.

[COMMUNICATED BY M. H. GERRY, JR.]

The maximum practicable limit of pressure on transmission lines has been frequently stated as fixed at a certain voltage, but this limit has as frequently been extended, with good results. At the present time, no considerable difficulty should be experienced with 100,000 volts, and there is no good reason to fix the limit at that figure.

The problems of insulation are becoming better understood, but there is still much to learn. The capacity and the surface effects of line insulators have received but little attention from engineers and many of the failures are due to this fact. The form of the insulator and the material have not, in general, received the proper treatment. A desirable insulator for high tension is not merely a piece of glass or porcelain arranged to shed rain, and of sufficient thickness to resist puncture.

The materials for construction of insulators are not so limited as assumed in the past. Glass and porcelain have been used almost exclusively, but from the experiments of the writer the material of greatest promise for high-tension insulators is prepared paper. Organic material, such as paper, has great advantage and is well suited for this purpose. Compound insulators in which the petticoats and water-sheds are made of metal, and the core of glass, porcelain, paper or other insulating material, are also feasible.

For moderate tensions, up to perhaps 30,000 volts, insulators having metal tops and outer petticoats are not only perfectly feasible, but are very desirable, and can be made very strong and practically indestructible, and much superior to the common glass or porcelain types now in use. For high voltages, the entire insulator can be made of prepared paper, or of a combination of paper with glass, porcelain or other insulating materials. Insulators on these lines may be designed for almost any desired pressure obtainable with commercial transformers, provided that all the conditions are properly understood in advance.

The writer has tested and experimented with nearly every type of insulator manufactured and with many special forms and constructions, and his conclusions, as stated above, are based on this experience, coupled with that gained from the practical operation of the highest-voltage transmission in commercial service to-day.

[COMMUNICATION AFTER ADJOURNMENT BY W. N. SMITH.]

An important matter that has not been touched upon in this discussion is the design of the pole-top pin, which, on a single three-phase transmission line, is of equal importance with the cross-arm pins. As in other details of line construction a variety

of methods has been followed, of which some are doubtless better than others as regards their mechanical features. In the construction that has come under my observation, either the top of the pole has a hole bored vertically to receive a bolt or the shank of a wooden pin, or else a so-called "ridge iron" has been lag-bolted to the pole top, with the usual wood or porcelain fittings for carrying the insulator. Sometimes an ordinary oak bracket is framed into the top of the pole, the roof of which is shaped to accommodate it.

Without entering into a discussion of the relative merits of these or other methods, it seems to me that there is enough difference between all the methods in vogue to warrant an attempt at standardization. This subject would, therefore, seem to be a proper one for the careful consideration of the Committee on High-Tension Transmission.

[COMMUNICATION AFTER ADJOURNMENT BY J. R. ARMSTRONG.]

Relative to the discussion on "Insulator Pins for High-Tension Transmission Lines," the iron pin seemed to be spoken of favorably by a great many present, but to me this iron pin has one great disadvantage (leaving the difference of coefficients of expansion of glass and iron out of the question)—nearly every pin has a burr on the end, due to the way in which the ordinary pin is manufactured.

Now, there is a tendency to a continual discharge between the line and this burr or sharp point on the other end of the pin. This, after a time, cuts through the glazed finish of the insulator, and consequently causes the breaking down of the insulator.

Also in the same discussion, one of the objections raised to the use of wooden pins was that of the corroding at the ends and sides.

I would just like to raise the question: if nitric acid is formed as was suggested, could not some base be used, which would form a neutral salt with nitric acid, the pin being treated in some way with this base.

[COMMUNICATION AFTER ADJOURNMENT BY F. S. WOODWARD.]

During the discussion relative to the breaking down of insulators and the burning of high tension insulator pins, one possible cause of the trouble was not stated. It may sometimes be due to the method of fastening the tie wire to the insulator. In many cases I have known linemen in making what is known as a pigtail tie, after the wire was finally twisted, to bend down the end of this pigtail so that it came in contact with the surface of the insulator at a point near the lower rim; the distance between the edge of the rim on the insulator and the end of the tie, depending, of course, upon the tie's length. This would reduce the amount of creepage surface between the pin and the tie wire, which partakes of the line potential. In this connection it might be well to state that in some cases spun yarn, thoroughly saturated in tar or asphalt or in P. & B. paint, makes a good substitute for tie wire, the coating practically protecting the spun

yarn against weather effects. It might not, however, be serviceable upon a line under the conditions of voltage as described by Mr. Buck, where the surface of the line wire and of the ties showed signs of reaction due to the formation of nitric acid, which would probably affect the vegetable fibre of the spun yarn in the manner indicated in the case of the thread of the insulator pin. I regret that Mr. Buck did not state the size of the iron wire used on their experimental 75,000 volt line. I recall the paper published in the Transactions on the "Dielectric Strength of Air," by Mr. Chas. P. Steinmetz, in which he gave an account of a number of experiments on the sparking distance between sharp points, between spheres of various sizes and cylinders of various sizes. The lower portions of the curves, as I recall, departed more and more from the straight line effect as the voltage was reduced and radius increased. It would be interesting, in this connection, to follow out these experiments and see whether a change in the diameter of the wire (practically being a continuous cylinder) would stop sparking or brush discharge at the desired voltage. For instance, if the wire in Mr. Buck's experiment was a No. 8 and the wire in the second experiment was a No. 1 or a No. 2, if the increased radius would so modify the curve that the brush discharge and the probable formation of nitrogen would be prevented.

As a sequel to the discussion on pins and insulators, it would be a very desirable thing to take up and standardize the cross-arm to which these pins are attached. Also that the distance between wires and the most desirable method of spacing same should be outlined in the report of the Transmission Committee.

COMMUNICATION AFTER ADJOURNMENT BY HENRY FLOY.

Fearing that the remarks of some of the speakers may have left an erroneous impression as to the potential of telephone circuits carried on the poles of high-tension transmission lines, I desire to state that some measurements made by a Weston voltmeter between the conductors of a telephone circuit placed five feet below the conductors of a 25,000 volt overhead circuit and ground, showed the potential to be only from 140 to 160 volts. Similar measurements on a telephone circuit three feet below a 10,000 volt line showed only about 95 volts to ground and, naturally, no difference of potential between the telephone conductors. It seems to me that the voltage of a telephone circuit given as 20,000 by Mr. Thomas cannot be such potential as would be indicated by a voltmeter or such as would cause particular damage, being, I assume, simply static potential.

Referring to the suggestions made as to signaling in case of partial breakdown of the telephone system, it has occurred to me that as a relay to the telephone circuit, a system of wireless telegraphy could be installed without large expense, which might advantageously be used in transmitting signals in case of trouble with the telephone circuit.

BRANCH DISCUSSIONS.

DISCUSSION AT MINNEAPOLIS, MARCH 6, 1903.

During the reading of the paper on "Some of the Problems of Electric Train Lighting," Mr. Shepardson described the Gould system of axle lighting, which had not been represented in the papers, noting its development from the Stone system, which is largely used in Europe. The dynamo is thrown into or out of circuit by a centrifugal governor on the armature shaft, which operates at a definite speed. Regulation is obtained by mechanical means, the adjustment of the belt being such that it delivers any desired torque to the armature shaft and slips if the peripheral speed of the driving pulley exceeds that of the driven pulley, which would cause the armature to develop more than the desired current at the desired voltage. Careful selection of materials for the belt and the pulleys secures the unusual result that the slipping occurs on the larger driving pulley rather than on the smaller armature pulley, thus localizing the heat developed from slipping at the car axle pulley, where there is a large surface for cooling. Adjustment for any desired strength of current is secured by changing the tension on the belt. In practice there is found to be considerable variation in the belt tension when the car is rounding curves, for the dynamo is mounted on the car body and its spring suspension does not entirely prevent wide variations in belt tension when the car-truck swings. These variations in the current are absorbed by the storage battery, so that the voltage is sensibly constant.

Attention was called to tests upon the Muskowitz system formerly used on the Santa Fe road, in which the dynamos had a triple field winding; a high resistance connected across the battery for the purpose of insuring prompt excitation, a second winding connected in shunt with the armature terminals, and a third winding in series with the armature, but connected so as to oppose the two shunt windings. The combination of the three windings was supposed to secure constant current and constant voltage for any train speed above that at which the dynamo was thrown into service. A series of tests by students of the University of Minnesota developed the fact that close regulation was actually secured by slipping of the belt as well as by the differential winding, thus classifying it in principle with the Stone system.

Discussing the costs of various methods of lighting, data were quoted from the records of one of the large railroads which had had long experience with different systems, showing the cost of lighting a 60-foot coach with 262 candlepower 5 hours per day and 365 days per year, to be as follows:

Oil	\$113.43
Acetylene, gas generated on the car	236.05
Pintsch gas, equipment bought, gas made by R. R.	262.04
Pintsch gas, equipment bought, gas bought	246.35
Pintsch gas, equipment rented, gas bought	309.75

Storage battery, charged at terminal stations	256.87
Dynamo and engine, full storage battery auxiliary	254.68
Dynamo and engine, Pintsch gas auxiliary	315.29
Dynamo and engine, oil lamp auxiliary	194.51
Axle system no auxiliary	268.70

In justice to the axle system, it should be stated that this company has only a very limited number of axle lighting-equipments, no two alike, some operating under unfavorable conditions, some much more expensive than others.

Another large road which has a larger number of axle lighting-equipments in service, reports an expense of 18 cents daily for labor, which with 5 per cent. interest and 5 per cent. depreciation and \$4.00 per month for power, makes a total of \$13.00 per month or \$156.00 per annum for the axle system. If longer experience justifies the latter figures, the axle systems can compete with every other lighting system, except possibly oil, on the basis of economy. Considerations of safety, independence, convenience, comfort and absence of disagreeable features should leave little doubt as to the best system of lighting.

DISCUSSION AT PHILADELPHIA, MARCH 9, 1903.

CHAIRMAN CARL HERING:—As the three papers on Train Lighting are very much alike, I think it would be better if we had all of them read before beginning the discussion. This is the method usually practised at the New York meetings of the INSTITUTE; unless there are objections, I shall call upon Mr. Bliss to present his paper first.

Mr. Bliss then read his paper. (See page 309, March Transactions.)

CHAIRMAN HERING:—In the absence of the other two authors, Mr. W. C. L. Eglin has been so kind as to abstract their papers. Mr. Eglin will please present these abstracts.

Mr. Eglin read abstracts of the papers by Messrs. Farnsworth and Sperry.

CHAIRMAN HERING:—The matter is now open for general discussion. There are some gentlemen here who have had experience with these systems. We would be very glad to hear from them. May I ask Dr. Dudley to say a few words.

DR. DUDLEY:—I am as deeply interested, I think, as any one can be in the successful lighting of railway cars by electricity. I worked very hard at it in connection with the Brush Company and their expert during 1882 and following. I am frank to say to you, however, as a result of a good deal of hard work and some failure, that I am just a bit skeptical even yet as to whether we will be able to solve this problem. I don't want to be a wet blanket in any shape, but the difficulties have been discussed before, somewhat, and in talking with Mr. Wood, electrician of the road, a few days ago, I found that though he, like most electricians and like most others who are dealing with nature, was very enthusiastic a year or two ago, he is less enthusiastic to-day. Three plans for

railway car lighting have been mentioned as feasible. First, storage batteries alone. That is what we used in 1882. We called it the transfer system. We used two batteries; one off, the other on the car, and each battery large enough to light the car for a definite period of time. We charged one at the station, while the other was used on the car. Since that time we have been charging a battery at Jersey City and one at Chicago. At one time we were inclined to believe that this plan would be entirely successful, because it is possible to fit a car with enough battery power to light it for any given run between Jersey City and Chicago, and then take it out and put another battery in its place, and so operate continuously. The storage battery has progressed materially since the day we began, but, I think that any man who has to do with it will wish it was a better apparatus. So much for the storage battery. The second plan is the generation of electric current by the movement of the car. That has already been discussed and we are hoping for a great deal from the device described. The third plan is a system now and for quite a time past in use on the New York and Chicago Limited, namely; an engine in the baggage car operated by steam from the locomotive, a dynamo in the car and storage battery under the car. A fourth system is also being studied; that is, putting some sort of generator on the locomotive. A generator operated by a steam turbine has been suggested and is now being experimented with at Albany. Some years ago we used to say that a car must be self-contained for three things: For its light, for its heat and for its ventilation. As you doubtless know, in the progress of time the heating has been made a train unit. In other words, we heat cars by steam taken from the locomotive, and the independent car heater has been superseded. It is possible that we may make the car self contained so far as lighting is concerned by an axle-driven device. Besides experimenting with axle-driven devices, the tendency is toward making the train the unit, generating the current on the locomotive itself. I am sorry not to have any positive data to give you regarding the operation of some of the axle-driven devices. You are doubtless all familiar with the very serious difficulty of trying to operate by means of belts. As far as experience goes, that is almost insurmountable. The device Mr. Bliss described we regard as the best we have ever seen and the best we have ever experimented with.

I noticed in Mr. Sperry's paper something in regard to costs. If I have read it rightly, Mr. Sperry makes out that the electrical lighting of the train is considerably cheaper than other methods of lighting. Now, it is desirable to make a distinction. We do not calculate the cost for lighting by the same method that he calculates it. It is a question of lighting the car and not a question of cost per candle power per hour. If you light a car with an arc lamp you can generate your light per candle power per hour for probably a tenth of what it costs by any of the present

systems. But the distribution of the light is an essential feature, and an arc lamp is hardly a good light to have in a car. Mr. Sperry's figures are based on the cost per candle power per hour. We light our cars, approximately, with gas, giving a total illumination of one hundred and fifty candles, and with electricity possibly two hundred to two hundred and fifty—maybe more—Pullman cars a good deal more. If we consider candle power per hour, electricity comes out ahead. If we consider car lighting per hour, we find the gas system a good deal cheaper. We had a long discussion over this some months ago and I might have brought some figures showing the relative cost of lighting a car an hour by different systems; but as my memory serves me, it costs considerably more to light a car per hour with a fairly satisfactory light—not all the same candle power, mark you, but with a very satisfactory light, by means of electrical devices, than by gas.

CHAIRMAN HERING:—I would like to ask Dr. Dudley whether the unit is the same in the two cases? You say it costs more to light by electricity than by gas. Do you base that on the number of candles being the same?

DR. DUDLEY:—No, you can't do that. I tried to make that clear.

CHAIRMAN HERING:—But any other comparison is unjust.

DR. DUDLEY:—Suppose you have a thousand cars to light, how much will be your bill for lighting? That is the problem the railroad man has to look at—how much for car lighting this year? You light your car with any kind of light that is satisfactory. You can put in double light and the cost per unit will be cheaper but the total amount for car lighting will increase.

CHAIRMAN HERING:—It seems to me that must necessarily figure out. When you light them electrically you have a great deal more light.

DR. DUDLEY:—We agree to that.

MR. BLISS:—There is nothing at present that we know of that is perfect. Some things are better than others, and in bringing out a new thing it is necessary that it shall be enough better than that which it superseded. Dr. Dudley says it would be very cheap to produce light in a car from an arc lamp, per candle power per hour, but that the distribution is a question that cannot be lost sight of. That is admittedly true, but it is not perfect distribution that we have to compete with. We simply have to compete with gas, and we all know that the distribution of light in a car by gas is anything but ideal. The eaves and flies of the car, to use a theatrical term, are pretty well lighted, but the parts where the passengers are are not well lighted, and the distribution, while the value cannot be reckoned in dollars and cents, nevertheless has a value, and when produced even at a greater cost than gas, it still has to be borne in mind that the new value that has been introduced tends to reduce the actual cost of the light. Now, in a Pullman

twelve section sleeper, the maximum available candle power, with the largest outfit ever installed, is about three hundred and fifteen candles. Taking gas at twelve candles per cubic foot, which is rather high, that would be sixty candles per five cubic feet, which is the standard with the gas makers. But three hundred and fifteen candle power is not enough to light a sleeper or parlor car adequately; with such a system as we have attempted to develop, the available candle power is about six hundred and forty. Not only is the candle power more than double, but the distribution should, in a measure, tend to reduce the actual cost of the lighting, if the quality of the light is a factor. It is very difficult to build this electrical apparatus small enough so that when fully loaded it will give little enough light to be comparable with gas. It is the conditions—the construction of the truck and dimensions which make it rather difficult to build a very small machine.

A machine, to light a coach as it is lighted to-day, ought to be about one-third of the size of our present generator; so that the machine we turn out to-day is really altogether too large for a coach, if that coach is not to be lighted any better than it is to-day. Now, as a matter of fact, the coach could be lighted so that it would look so entirely different from the rest of the coaches that it might make an unfavorable contrast, and it may be for that reason that the railroad people may not wish to put in so much light in the car. We could not make a generator, built on the lines that we have laid down, very much cheaper if it was designed simply to do less work. There are certain dimensions that fix the size of the machine. For instance, the driving gear is dependent upon the size of the axle.

MR. POPE:—Would we not meet Dr. Dudley's contention by distributing the light over more cars. I think Dr. Dudley suggested in the early part of his remarks that possibly the axle system might take the place of the single generator in the baggage car? Can you light two or more cars from the generator as it is now?

DR. DUDLEY:—I will only say that if we were perfectly satisfied with the present gas system we would not go into a new device. We are not satisfied; we want a good deal better light and we expect to pay for it. In answer to Mr. Pope, the idea of having every car lighted from the generator is absurd, if he will excuse me for saying so. The car has got to be a car. It has got to have certain things self-contained in it. We cannot often make up trains as we like. I have seen local trains going out made up of four combination cars. You understand what a combination car is. It was simply impossible to get the other cars in in time to make schedule. Every car must have its own light or whatever is essential for its production and operation.

CHAIRMAN HERING:—If Dr. Dudley will favor the Secretary with the data covering his experiment, he will be very glad to publish it.

MR. POPE:—I wish to explain, Mr. Chairman, that my remarks are due to Dr. Dudley's statement, that originally a car was self-contained, as regards its heating, ventilation and light. But we had got beyond that. The train was the unit now, and therefore the lighting system might be installed in a baggage car. For that reason I asked whether this was a possible development.

DR. DUDLEY:—I see the point. The only train equipped with the lighting system in the baggage car is the New York and Chicago limited. Its cars are always kept together in the same train. With the ordinary passenger coach that is not true, and the main line of the Pennsylvania is not operated that way. The car must be available for various kinds of passenger service, especially in local traffic. We cannot have, transportation officers tell us, certain cars assigned to certain trains. There are a few run between Broad Street and Jersey City that are made up of the same cars and come back the following day, but for the bulk of the local traffic we have to use any car that is available when a car is wanted.

MR. POPE:—I was not alluding to your electric lighting of local trains. I don't think I shall live long enough to see that. Any old thing will do as far as that goes.

CHAIRMAN HERING:—Are there any storage battery engineers here to-night? Is Mr. Lesley here, of the Storage Battery Company? Perhaps Mr. Lesley will tell us about storage batteries.

MR. LESLEY:—We are probably the firmest kind of believers in the storage battery car lighting used since 1882. We have had personal contact with them since 1888. We feel that the battery is now a thoroughly commercial article, and used in connection with the Bliss system, I think that the railroad people will find them all that can be desired. Batteries used in train lighting see very much more severe service than those used in stationary work. I believe the railway people thoroughly understand that and make the necessary allowances. The batteries used for train lighting are especially designed for that kind of work. I do not know that I can say any more. I am ready to answer any questions.

CHAIRMAN HERING:—Have you any data concerning the life of batteries used in this way?

MR. LESLEY:—That depends very greatly on the use of the system. We have batteries in use on the Atchison Road which have been in four years, if not five. The boxes are not in so good repair as they might be. Out in Arizona the temperature gets up to one hundred and thirty. We all know that high temperatures are not conducive to the best service from a storage battery.

CHAIRMAN HERING:—What system is used in that line you speak of?

MR. LESLEY:—The Consolidated system. It has been in use now since 1894 or 1895.

CHAIRMAN HERING:—Is that an axle-drive system?

MR. LESLEY:—Yes; the axle-drive system with controlling devices, slightly modified from those originally used. They had two batteries in service alternately, now they have one battery.

CHAIRMAN HERING:—Is Mr. Woodward of the Storage Battery Company here?

MR. WOODWARD:—I think there is hardly anything I can say of interest on this subject to-night. My work is largely on the other side. I do not know that there is anything I can add at all to what Mr. Lesley says. If there is any question I could answer in any way, I would be very glad to do it.

MR. HEWITT:—What kind of plate do you use now?

MR. WOODWARD:—For car lighting the plate used now is Manchester type of positive—somewhat similar to stationary battery work.

MR. HEWITT:—Has that road made any comparison between gas and electricity?

MR. WOODWARD:—That I don't know.

MR. HEWITT:—What is the size of those plates?

MR. WOODWARD:—About seven inches square.

MR. HEWITT:—What is the weight?

MR. WOODWARD:—That depends. There are two or three sets of batteries used for that equipment—nine, eleven and fifteen plate cells. I do not know the exact weight.

DR. DUDLEY:—It might be interesting to ask some of the storage battery people if they would be willing to guarantee the life of storage batteries. The duration of the battery is quite a large element in the cost. In our calculations the rapid deterioration of the battery was quite an important item. We will assume that the train arrives at Altoona and has more cars than passengers over the next division; then it is deemed advisable, for transportation reasons, to take a car out and it is put on a side track. Some of these cars may stand idle for quite a period of time; they may stand two weeks without getting into a train at all. Now, the deterioration under those conditions is somewhat greater than in daily service; yet it is an essential condition that a car must necessarily stand. The battery undoubtedly has been improved very greatly by the efforts of men here to-night, within the last five or six years. In our first work the life of a battery was very short. A year was about as good as we could get, even with an old Brush battery. It would be interesting to know the guarantee that could be used as a safe figure in estimating on the cost of car lighting where the battery is the element.

MR. BLISS:—A storage battery is really not a bad thing. We have all been interested in the announcement that Mr. Edison has made from time to time of what he is going to do with a battery, but even he is on record as having once said, when he was asked what he thought of a battery, "Well, the damned thing is wet." That is the greatest drawback—being wet. It

does slop around a good deal. It not only produces deterioration in itself, but it produces a good deal of deterioration in other things—principally the metal work of the containing boxes in which the batteries are held, men's clothing and anatomy. But the storage battery, when put on a car and properly covered (and that cover needs be especially tight fitting to keep down a little slopping that may occur) does not give very much trouble; but where batteries are handled as Dr. Dudley described in the transportation system, a great deal of trouble does arise. In Jersey City, in the works of the Pullman Company, where batteries are handled continually, the continued slopping and shaking of the batteries when they are carried over tracks to get from the battery house to the cars, produces deterioration in the battery which is really excessive. It seems to me it can easily be avoided. Now, in some kinds of work, a storage battery gives a great deal longer life and a great deal more satisfaction than in others. I presume the most severe service to which a storage battery is ever subjected is that on an automobile, where the radius of action is guaranteed at fifty miles, say, and the owner is glad when he gets twenty-five. The storage battery is loaded up; and then it is drained down, which means a very severe service; and that, combined with the jolting and vibration, and the non-professional care it oft-times gets, runs up the depreciation. We all know that the central station battery cannot depreciate very much, for two reasons: First, because it stands still, and is not allowed to slop about; and secondly, it is never charged to its utmost capacity and never drained out clear to the bottom. The same is doubtless true in car lighting. Now, a car is not such an extremely rough place to carry a battery as you might suppose. I have seen storage batteries on the railroad cars that are continually covered with railroad dust, where the presence of a drop of acid would be noticed; yet those batteries would be just as dry as a chip for months and months. No particular trouble from slopping was discernible, and if those batteries are used—not as stray storage batteries and loaded up to the utmost and drained down, as in an automobile, but are operated in connection with some kind of generating system, either directly by a steam engine in the baggage car or in connection with an axle-system, provided the axle system holds together and does its work—the batteries will hold out and show very good life. I can relate one specific incident that will illustrate my text. I was operating a car on the Congressional Limited, the battery being furnished by the Pullman Company. Unknown to me, Mr. Loeb, the electrician of the Company, found it advantageous one day to steal this battery for use on another car; not to leave me in the lurch, he improvised a battery which was made up from stuff that had been condemned and thrown on the scrap heap, and put that on the car I was trying to operate. I didn't notice it until about two months after, when he came to me one day and said: "I played a trick on you not long ago, giving you

this scrap. I have examined it and I see you have it formed up into pretty good shape. I guess I'll let it stay." Really, the service is not so hard provided the batteries are not subjected either to rough handling or too excessive discharging or overcharging.

MR. EGLIN:—I have listened to Mr. Bliss' paper with a great deal of interest, particularly as four years ago I had occasion to investigate axle lighting-systems. At that time Mr. Bliss' system had not been produced. In going into details I found that over 90 per cent. of the trouble encountered was in the drive. In the early days a belt drive was used, the belt being driven on two flange pulleys; the theory being that the flanges would keep the belt on. As a matter of fact, however, the flanges seemed to be the source of trouble, as the belt would ride up on the flange and tear. After abandoning the flange pulleys, we had better results.

The records on the road that I was interested in investigating covered a period of more than a year at that time, and they had tried every conceivable form of belt without success. On every trip on this particular train at least one belt had to be renewed. The life of a belt was about six weeks or less. They carried a man on the train to look after the repairs, but his principal job was to put on belts. The comments of Messrs. Sperry and Bliss on the storage battery, applied at that time, too, because some batteries were old and useless. It seemed that their only function was that of acting as regulators. This particular system did not use boosters; it used rheostats. The field-built up so quickly they had to have an artificial load to keep down the rise in voltage. I tried every conceivable way to upset the scheme in the electrical part. It worked perfectly except when the battery was cut out, when the e.m.f. jumped up to a hundred volts. It is evident that the battery is not the important part of the system.

The most important part of the axle system is in the driving and this seems to have received careful attention by Mr. Bliss. The question of electrical efficiency of the generator storage battery and electrical device is of secondary importance. The advantage of using boosters in place of rheostats for this class of work will not materially change the total efficiency, because the total power used per car is very small, and that is one of the important features—that it does not require any power at the time the train is being accelerated, as the generator runs free until the train attains a speed of eighteen to twenty-five miles per hour. The system of axle lighting upon each car seems to me ideal, and would best fulfil the conditions of railroad service as each car is a complete unit and can be put into any train for any service. On the other hand, the locomotive is also a necessary unit to every train, so that the generator set could be made small enough to be put on the locomotive and be of such character as to require very little attention; for example, a steam turbine set. The power for the lighting of the entire train to be supplied

from these generators, and batteries being installed in each individual car to supply the lights when the engines are being changed. This would place the minimum amount of work upon the batteries and place the electric generator and its drive in a much more accessible position and in a location where it would receive reasonable attention. With the developments of the steam turbine which are now taking place, I think that this system should at least be given a trial.

The mechanical conditions of driving a generator under a car are exceptionally severe. First, on account of the danger of the ballast interfering with the belts—there are a number of cases on record where stone ballast has been raised from the roadbed and located between the belt and the pulley, cutting the belt. Secondly, on account of the large range of temperature through which a train may pass on a single trip, ice forming on the pulleys causing the belts to break or throw off. The cost of power of operating the train lighting from the axle system has been demonstrated, the most important item being the cost of maintenance. The expenses could be divided into three heads: interest, depreciation and maintenance. The first is easily determined, and the second and third depend upon the care and forethought that have been exercised in designing apparatus destined to withstand so severe a condition of service. In the operation of 104 cars provided with the axle system, sixteen men were constantly employed in maintaining the system. It is evident that the entire cost was in this maintenance account. As almost two-thirds of this force was employed almost continuously in maintaining the driving device it is evident that if a suitable drive could be provided, either frictional or gearing, the cost of operating such a system can be materially reduced. At the time I made these investigations, proper allowance was made for maintenance account, and the cost compared very favorably with the lighting per car—not with the unit of candle power—which was charged at that time by the Pintsch Gas Company. These figures were based on throwing out a belt drive and substituting a more satisfactory method. The question which Dr. Dudley stated, that the Railroad Company wanted an improved light seems to me a rational one. The old oil light was not discarded because gas was cheaper, but because gas gave a better light, and the Pintsch gas was substituted for the same reason.

The electric lighting of cars meets all the conditions from a lighting standpoint, required by the railroad company. First, it is not affected by air current or changes in temperature; it can be placed in any location desired; and the current can be used for heating purposes or for motors. It is impossible to install gas berth-lights on account of the dangers of fire, and it is impracticable to operate fans with gas motors. The berth-light is an added luxury, and is much appreciated. Persons would rather ride on a train lighted by electricity than one lighted by gas. The question of actual cost of lighting would not deter a

railroad company from using an electrical system, provided they could place some reasonable value on the cost of maintenance.

The cost of maintenance of an axle lighting-system has been very heavy, but the railroad company has had no means of properly determining this as the manufacturer has generally maintained his own system. Considering that this system is twenty years old and until recently not fully developed, one cannot blame the railroad companies for moving cautiously. It is particularly gratifying this evening to see how far and how completely the mechanical features have been worked out, and I hope Mr. Bliss will have the success he deserves.

DR. DUDLEY:—There is one point I don't want to get away from, since we have storage battery people here. Is it, or is it not true that a storage battery, standing and not in use, loses current at such a rate that if it stands a considerable length of time the battery will deteriorate? Of all the passenger coaches that a railroad has, almost all of them are in maximum service for about seven or eight months in the year; three or four months in the year the equipment is not all used. What are we going to do with the batteries in those cars? With the gas system, if you leave the gas out a little bit you put more gas in and your system undergoes no deterioration, but if your battery is badly sulphated where are you?

CHAIRMAN HERING:—Will Mr. Lesley favor us with an answer?

MR. LESLEY:—Allowing that a battery is in reasonably good condition—and the batteries used in the axle lighting-system, as they are to-day, would come in in practically a charged state—it can stand a month without any serious amount of sulphating. If a battery is in the house longer than that, I would consider it advisable to have it charged at the end of the month, and I should think that could be easily arranged for in the shops. It is not absolutely essential, but advisable.

CHAIRMAN HERING:—Mr. Reed has had considerable experience with batteries; perhaps he will favor us with some remarks.

MR. REED:—I have never had any experience with train lighting. I have done some experimenting with the storage battery for many years. I have never yet run across a battery like that described by Mr. Lesley, which is all that could be desired. In fact, my experience with batteries has been just the reverse. If I could find a battery of that kind, I should be strongly tempted to try to infringe on it without having to pay damages. My opinion is that the point which Dr. Dudley makes in regard to batteries standing is pretty well taken. I think that a battery treated in that way does deteriorate. I gave up the idea some years ago of ever being able to get a battery that was all that could be desired, and since then I have been trying to get a battery that was very cheap so that it could be renewed at very little cost, paying less attention to trying to make it last a very long time; but so far I have not succeeded in getting a battery that inspired confidence.

THE PRESIDENT:—Mr. Elgin promised to give us an abstract of the discussion held in New York.

MR. EGLIN:—Mr. Chairman, the discussion this evening has covered most of the points that were brought out at the New York meeting, and I feel a repetition of them would not be of special interest, but there was one point brought out at the New York meeting which has not been touched on, which was that the best solution for the train lighting was to operate electrically the entire road; that is, if you are going to supply the lights electrically, why not operate the road electrically? This is a question for the future to discuss, and I did not think it belongs in this discussion.

MR. BLISS:—Of course electrifying the road and getting the light in that way appeals to everybody as the ultimate solution; but if we gave a light that in any way compares with the Brooklyn Rapid Transit, we would be jeered at.

MR. SPALDING:—I understand that on some railroads they use electric headlights. I think there is a unit of some kind placed on the engine back of the headlight, and the power is obtained from the engine itself.

CHAIRMAN HERING:—Can you say anything about that, Dr. Dudley?

DR. DUDLEY:—I never experimented except on lines East of Pittsburg. In many places the road is so crooked that if we had a million candle headlight it would not do any good, and so a headlight is regarded as a good sort of thing on a straight but not good on a crooked road that has many cuts. I have never seen them tried.

MR. KLUMPP:—The light spoken of by Mr. Spalding is a small generator and steam turbine placed in front of the smokestack; the whole apparatus is not more than fifteen inches square.

DR. DUDLEY:—Where is that used?

MR. KLUMPP:—On several roads. It was written about in several papers lately. I do not know whether it is in the experimental stage or on the market now.

There being no further discussion, the meeting adjourned.

DISCUSSION AT SCHENECTADY, APRIL 7, 1903.

DR. F. A. C. PERRINE:—There is so much in these papers, that it is hard to enter upon a discussion of them. In regard to the paper by Mr. Mershon, I believe that there is one element in the strength of the pin which he has altogether neglected, which however, may possibly be neglected on account of the roofing or rounding of the cross-arm. I refer to the element of strength in the shoulder. The pin is discussed as a beam fixed at one end, and in consequence the ordinary parabolic section of the beam is brought out, because the fibers of the pin are considered to be in tension or compression. Now, as a matter of fact, if the shoulder is made pronounced and firmly fixed on the cross-arm, the pin is very much increased in strength; because there is an element of

the stress applied to the end of the pin, which is transmitted parallel to the side of the pin and against the cross-arm.

Mr. Mershon says that usually pins break off at the shank. This is generally the case where pins do not bear on their shoulder in the cross-arm. In some experiments made in the West with a number of pins, I found that if the pins were given a proper shoulder and made to bear in the cross-arm, they did not break at the shank, but broke diagonally from a point about at the end of the thread crossing the pin. The pins that were tested were approximately the same locust pins that were mentioned in the discussion. By giving these pins a proper bearing, the strength was found to be increased from 700 lbs. to 900 or 1,200 lbs., with approximately the same pin.

I notice that the pins designed by Mr. Mershon correspond very closely to the pin in Fig. 1 in Mr. Chesney's paper. Furthermore, I see that the pin in Fig. 1 in Mr. Chesney's paper is not given a bearing in the cross-arm, as the shoulder is filleted so that it does not come down to a solid bearing. The other pin in Fig. 2 is given a solid bearing, and this pin is very much stouter than the pin in Mr. Mershon's paper or the pin in Fig. 1. As you will notice, these pins are both for the same insulator. The pin in Fig. 1 is the pin used on the Standard Company's lines and in Fig. 2 the pin used on the Bay Counties lines. Mr. Hancock of the Bay Counties Company designed this pin after testing a number of pins and insulators. He found that the pin in Fig. 1 would almost invariably break before the insulator; that the pin in Fig. 2 would practically never break before the insulator, this pin having practically the same strength as the insulator. The material is eucalyptus. Since the discussion, Mr. Hancock has reported the strength of this eucalyptus pin compared with a steel wagon-axle. The axle was broken at a strain that would not break the insulator, although the wood pin was of approximately the same strength as the insulator.

The observation made in the discussion that Mr. Mershon's pin is based on a uniform stress applied to the insulator, and that this is not a reasonable specification for the standard pin, is a point that is very well taken. With lines such as are proposed now, with spans of five or six hundred feet, the transverse stress on a wire from one-half to three-quarters of an inch in diameter, will be in excess of 600 lbs. With oak or locust, as specified by Mr. Mershon, the pin will not have a strength much in excess of 600 lbs. With eucalyptus, it would have a greater strength, eucalyptus having approximately the strength of good hickory. In such spans of five or six hundred feet it would be necessary to install more than one of Mr. Mershon's pins to stand the strain from heavy cables.

In regard to the testing of glass insulators, so far as I am aware, having had experience with a good many thousands of glass insulators, the puncture of glass insulators by reason of breakage after the insulator had been inspected visually and

tapped with a mallet, is very unimportant. The point that Mr. Blackwell makes of glass insulators breaking down, due to lack of annealing is, on the contrary, an exceedingly important one. One of the lines in California installed a type of glass insulator that had been well tried, but apparently it received a batch of unannealed insulators, for before the end of the year a large number of their insulators separated and broke down; the head of the insulator cracked off and let the wires drop. Such occurrences with glass insulators, are far more important and more likely to happen than punctures. A glass that will puncture at all, I believe to be a glass that is so bad that you could see the defects. No insulator should be installed which has a bubble between the wire and the pin, because these bubbles are vacuums, and you might as well have just so much metal in the insulator.

Mr. Lincoln's paper, is I think, the first approaching a complete discussion of the telephone line transposition problem, and it is so complete that I cannot sit down without commending it, without saying that in my belief it contains the elements of the entire solution of this very important and difficult problem. Had this paper been printed four years ago, I believe that I know of more than one man's life that would have been saved by it. A very sad accident happened about a year ago: A patrolman starting out to work, went to the closed telephone box to report. In connecting this telephone to the line, he was killed. I believe the power line was grounded, but not to the telephone line. Since that, the Company has observed the rule of seeing that the operator is insulated as well as the line.

The question of potential to earth is the only thing that Mr. Lincoln has not given an absolute statement of, and I am inclined to think that that is because there is something in it that we don't yet know. Mr. Lincoln writes of the difference of potential, but says that that represents so small a current as to be inappreciable. If the surface of the condenser that is produced by the power line and the telephone line and the condenser of the telephone line and the earth is calculated, where the line is one or two hundred miles long, the amount of current that is transmitted will not be by any means inappreciable, and will be enough to give a great deal of trouble. This is the only criticism that I would have to offer to this most excellent paper of Mr. Lincoln's.

This model of Prof. Franklin's is a piece of education to all of us, not simply as a model of electromotive force, but because it represents the effects that take place where we have a line of one complete wave length.

*A paper read at the 2d Meeting of the Boston
Branch of the American Institute of Electrical
Engineers, March 26, 1903.*

A SYSTEM OF ELECTRIC LIGHTING FOR CARS.

BY JAMES F. McELROY.

A modified constant-potential system of car lighting, employing an axle-driven dynamo which is capable of operation by motion in either direction.

There is a wide variation in load which axle-driven apparatus is called upon to carry in actual service. If a car is operated wholly in day time, just sufficient current should be generated to maintain full charge in the battery or to supply battery losses; more than this amount is needless and wasteful and may be harmful to the battery-plates. On the other hand, if a car is operated only at night and must be lighted for some time before it begins its run, or has long and frequent stops, a very different problem presents itself. The battery should then receive its charge at a high rate and at the same time current must be generated for operating the lamps. In this case the current generated by the dynamo should be at a rate about twice that required for lamps alone. The actual demand upon lighting apparatus varies between the two extremes here referred to and consequently the lighting apparatus must provide automatically for correspondingly wide variations in load.

Incandescent lamps and storage batteries require constant voltage in the supply circuit. If a variable load is called for, it is evident that we cannot have a regulator controlled by the current in the mains as in that case there will be produced a constant current at a constant voltage, which will give a constant load. The variable load required must evidently be obtained by means of a constant voltage and variable current. These considerations should guide us as to the method of regulation to be selected.

The system of lighting cars which I will describe may be called a modified constant potential system. It employs an axle-driven dynamo which is capable of operation by motion in either

direction. Fig. 1 presents a view of the dynamo. It will be seen that the dynamo rests, at one end, upon bearings on the car-axle, while it is supported by easy-riding springs under the dynamo body. These springs rest upon curved supporting bars which are attached at one end over the car-axle bearings, and at the other end swing from pendulum supports to a cross-bar which rests upon the truck-frame. The dynamo is therefore free to move with the car-axle. The curved bar-supports facilitate the removal of the axle and wheels, when that is necessary, by dropping down out of the truck-frame in the usual manner. They also make it easy to open the dynamo as shown in Fig. 2 without



FIG. 1.

in any way releasing the dynamo from its supports. The dynamo is driven by means of gear and pinion in a manner somewhat similar to that employed on motors of trolley cars. A wrought-iron gear-case incloses the gear and pinion and is made dust-proof with leather packing.

All doors admitting to parts of the dynamo requiring inspection, as well as the doors for supplying oil and waste to the axle-bearings, close upon leather or felt packing and are held firmly in place by strong spring-latches of flat steel. All doors are in this way made dust-proof.

The compartment containing the reversing switch is shown at the left and in advance of the armature bearing. This switch is operated by the armature-shaft and reverses the connections of the armature to the mains. A door easily accessible admits to this chamber for purposes of inspection.

A storage battery is employed for supplying the lamps during stops. The battery receives its charge at all times when the dynamo is in operation, and the battery is below the point of full charge. The flow of current to the storage battery and the generation of current by the dynamo are regulated, through the

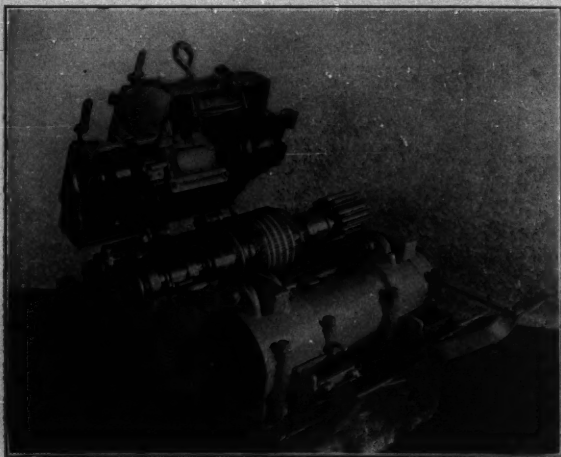


FIG. 2.

widest variations of speed, by means of the regulator shown in Fig. 3. In this regulator a motor, through worm and gear connections, operates a rheostat which is connected in series with the dynamo fields. The motor is controlled by a compound solenoid and plunger, the plunger being connected with an arm carrying carbon contacts by which the current is directed through the motor for changing its direction of motion. To insure the workings of the regulator under all conditions, it is necessary that the motor should be wound for large torque and low speed and be capable of operating at a voltage as low as the lowest voltage

ever carried upon a battery. It is also necessary that the changes in position of the rheostat should be made at a rate not greater than the rate at which the corresponding changes will take place in the field-magnets of the dynamo, otherwise the phenomenon of racing will cause a disturbance in the lights. To prevent racing, we use a centrifugal governor by means of which the circuit through the motor is completed between two stationary rings which surround the motor-shaft. Contact is made

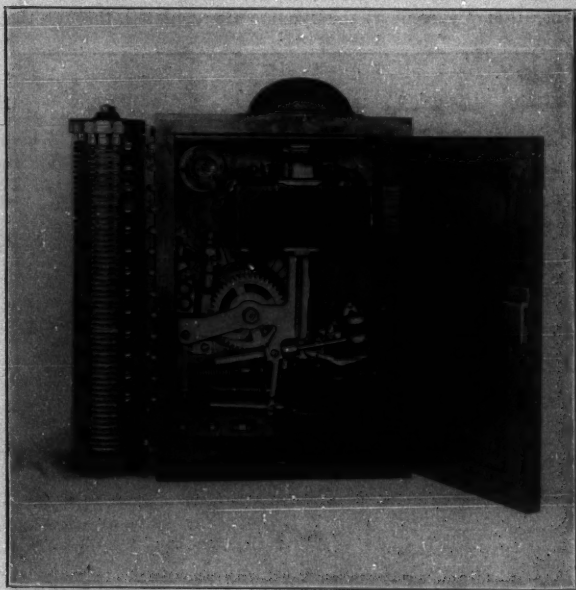
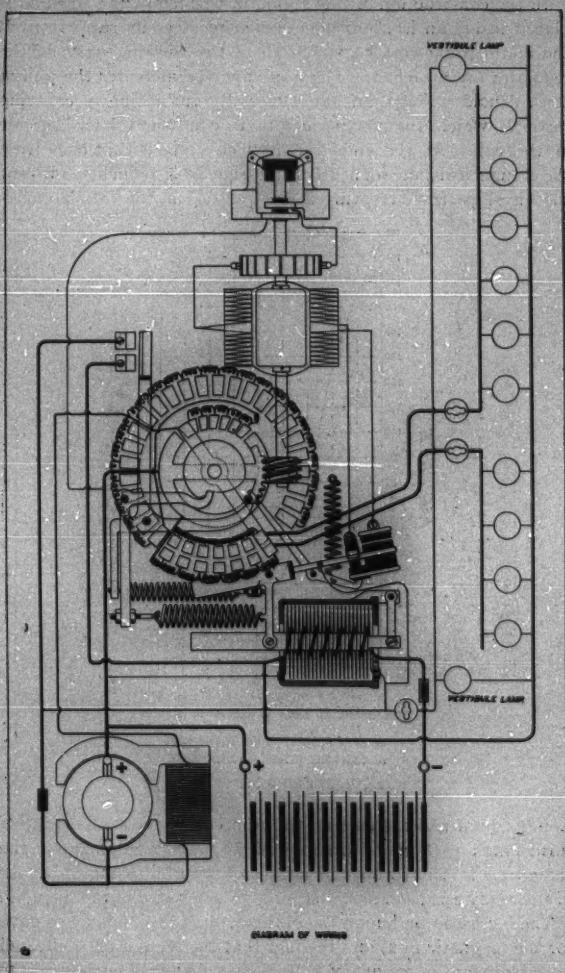


FIG. 3

between these two rings by means of weighted arms which on the starting of the motor, immediately throw out and break the circuit. The result is that the governor gives to the motor a fixed rate of motion and this rate of motion is not increased or decreased within the limits of voltage at which the motor operates.

The centrifugal governor is mounted above the motor and within the perforated hood at the top of the regulator.



In the construction of this regulator the compound solenoid is placed inside an iron envelope which receives its support from the metal framework to which all of the working parts of the regulator are attached. The iron envelope increases the pull of the solenoid more than two times by furnishing a covering through which the magnetic flux is conducted back outside of the coil. At the ends the iron envelope is kept back from the plunger a distance of nearly three-eighths of an inch, to prevent the envelope from creating a side-pull upon the iron plunger.

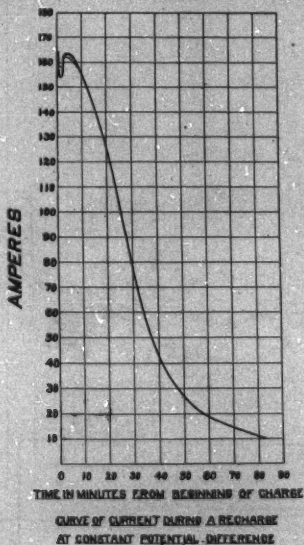


FIG. 5.

Longitudinal ribs are cast on the iron casing for the purpose of furnishing a path in the direction of the magnetic flux and at the same time for increasing the surface of the iron casing to permit of the ready escape of heat that may be generated in the solenoid.

The increased pull upon the plunger, due to the improved path for the magnetic flux, and the fact that the regulation is effected both by means of change of voltage and change of current to the battery, renders the apparatus very sensitive and positive in its action.

The switch for disconnecting the dynamo from the storage-battery is operated by the motor which drives the rheostat. The return of the rheostat to the home position when field-resistance is all out opens the switch and disconnects the dynamo. In starting the dynamo, when the dynamo voltage equals the lamp voltage, the first motion of the rheostat closes the switch and connects the dynamo and storage-battery together. A further rise of voltage causes the lamp-resistance to be inserted step by step between the battery and lamps and the battery begins to receive its charge.

The lamp-resistance is shown more clearly in diagram of connections in Fig. 4. The sections of this resistance are inserted as

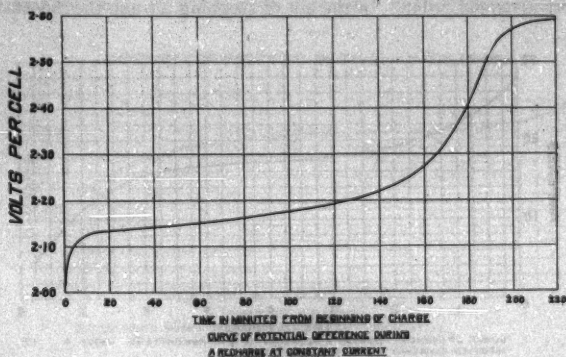


FIG. 6.

the voltage of the dynamo rises, causing motion of the rheostat-arm from its home position. The proper fall in voltage from that required for the storage-battery to the lamp-voltage is thus obtained. The lamp-voltage is that which the storage battery is capable of maintaining when the dynamo is not in operation. As the lamps are divided into two circuits, each circuit has its own lamp-resistance, which is inserted step by step by the rheostat-arm.

Vestibule-lamps are provided so as to give an abundance of light upon the steps and in the vestibules of a car when the train comes to a standstill. These lamps are preferably connected across the cut-out switch separating the dynamo from the storage-battery. The current for the vestibule-lamps therefore flows

from the storage battery through the dynamo and lamps in series. These lamps are lighted solely by the difference of the electromotive force of the dynamo and storage-battery. They are, therefore, lighted automatically when the speed of the train drops below twelve miles per hour, and come to full intensity at very low speeds and during stops. As these lamps do not draw upon the lighting apparatus during long runs, they can be made of ample intensity to furnish an abundance of light over the steps of a car at the time when the steps are in use, and at the same time do not draw upon the lighting apparatus at times when the lights in the vestibules are not needed.

The motor of this regulator performs a series of operations in a pre-arranged order. In the act of stopping a train, the rheostat

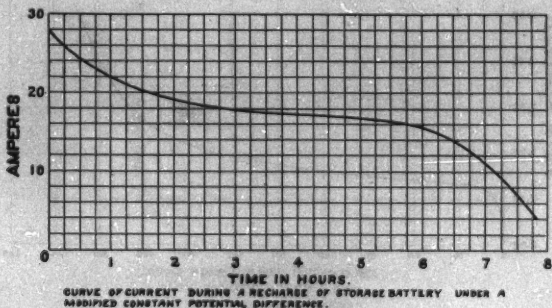


FIG. 7.

moves to its home position and cuts out the resistance in series with the field-coils of the dynamo. As it approaches the home position it cuts out the lamp-resistance and automatically changes the tension of the regulator-spring to change the adjustment of the regulator from the voltage of the dynamo when charging the battery to the voltage of the lamps. When the dynamo voltage reaches the lamp voltage, the motor opens the switch between the motor and storage-battery. A further movement of the motor opens up its own circuit so that when the car is at a standstill there is no circuit through any part of the regulator or dynamo through which the current of the storage battery is wasted. However, all parts of the regulator are then in proper position, so that when the dynamo current picks up and excites

the solenoid, the effect upon the plunger is: first, to re-establish the circuit through the motor which is done at the carbon contacts; secondly, to close the circuit between the dynamo and storage-battery and then thirdly, upon a further rise of voltage of the dynamo to cause the regulator to insert resistance in series with the lamps and in series with the field-coils of the dynamo.

In this regulator no motion of any of its parts takes place except when necessary to meet some change in the conditions of the lighting system. When the train is running at a constant speed the regulator is motionless. When speed increases, a slight motion takes place just sufficient to introduce the proper resistance in series with the dynamo fields to maintain the voltage constant. In this way we obtain the smallest wear of mov-

DIAGRAM FOR BATTERY OF TWENTY EIGHT CELLS.

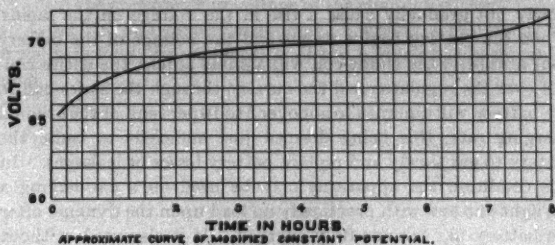


FIG. 8.

ing parts and the least possible care is required to keep the mechanism in order.

I have already referred to the fact that the regulator is controlled by a compound solenoid. I will now explain more in detail the construction and connections of the compound solenoid and the reasons for its use. By reference to Fig. 4 it will be seen that the compound solenoid is made up of two coils, one a large shunt-wound coil connected between the dynamo mains, and the other a small series-coil which is connected between the main and the storage-battery. These two coils act in conjunction when the dynamo is supplying current to the storage-battery and are opposed to each other when the storage-battery is giving out current. The compound solenoid draws the plunger against the tension of a spring. A motion of the motor always takes place

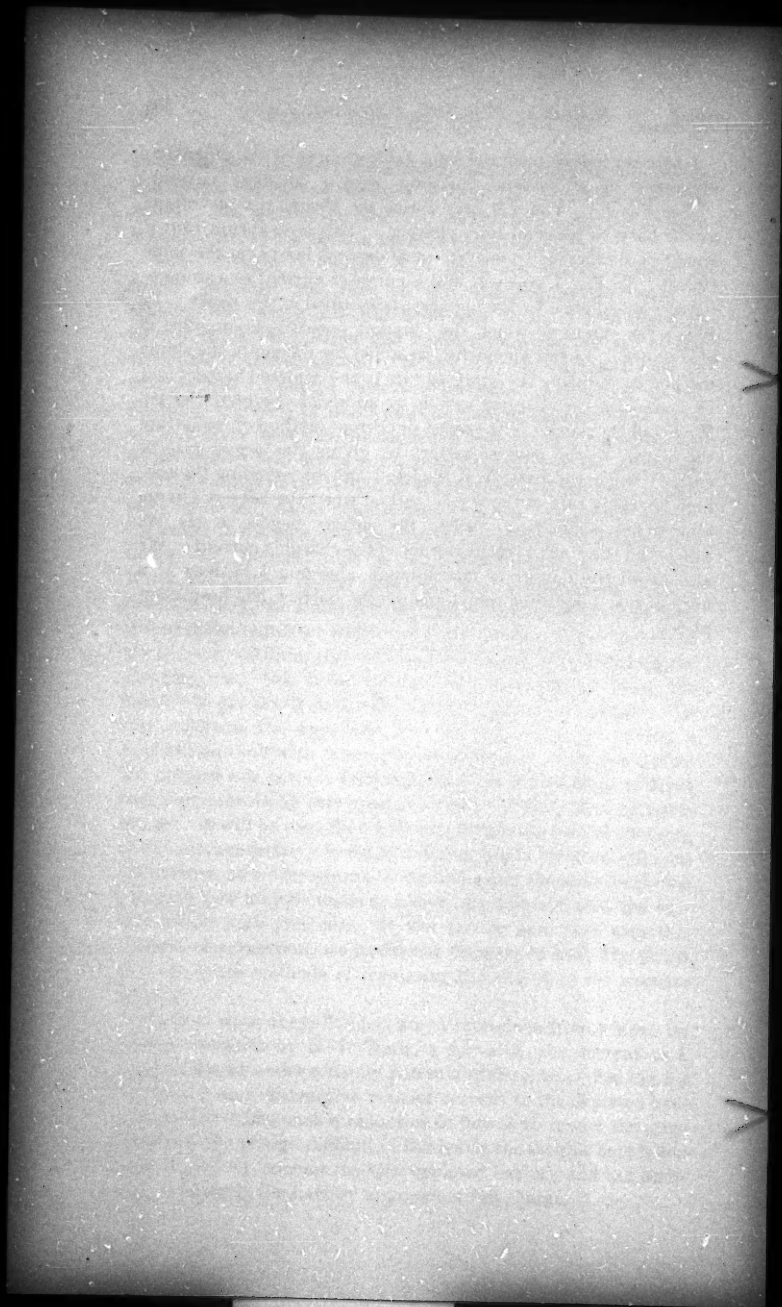
when the pull of either the solenoid or the spring predominates and causes the carbon contacts to close the circuit through the motor. The total of the effects of the two coils upon the plunger is equivalent to the tension upon the resisting spring.

Now, it must be evident that when the storage-battery is nearly depleted the rush of the charging current into it through the series-coil will cause the series-coil to increase its pull upon the plunger and hence reduce the voltage at the terminals of the shunt-coil. In this way the excessive flow of current into a depleted battery is prevented. However, as the charging operation proceeds and the counter-electromotive force of the battery increases, the decreased flow through the series-coil to the battery will decrease the magnetic effect of the series-coil and the voltage at the terminals of the shunt-coil will correspondingly increase. As the counter-electromotive force of the battery continues to increase, the decrease in the flow to the battery will slowly but gradually cause a rise in the voltage on the mains. When the battery begins to gas and the voltage of the battery rises abruptly, the shunt-coil will assume almost the entire control over the regulator and the current through the series-coil to the battery will diminish to not over 5 to 10 per cent. of the original charging rate, this being deemed just sufficient to cause the battery to gas slowly and replace battery losses or leakages. In this condition the apparatus may be used on a car having a daylight-run and with practically no load upon the dynamo after the battery has become fully charged. It is also used, without re-adjustment, upon cars operated wholly at night with all lights in use. It will be seen that with this simple device the charging of the storage-battery is made automatic and by proportioning the number of ampere-turns of the series and the shunt-coils the charging rate may be made to follow any formulæ that the battery-maker may prescribe. It will also be seen that with this method of regulation, we avoid the dangers of both the shunt and the series methods of regulating the charge to the storage-battery.

To show what these dangers are, I reproduce from a work on storage batteries by E. J. Wade, a curve of the current to a storage battery under constant potential-difference. (See Fig. 5.) The heavy and destructive rush of current to the depleted battery is followed by such a reduction in flow as to render the completion of the charge difficult. Evidently the trouble here is too great a rush of current to the depleted battery and not sufficient current as the battery approaches full charge.

I here reproduce from the same book a curve of the potential-difference of a battery charging with a constant current.

(See Fig. 6.) You will here notice the abrupt rise of voltage as the battery becomes fully charged. This is so abrupt that it would be dangerous to operate incandescent lamps on the same circuit. In Fig. 7 you will find a curve of current to a storage-battery as supplied by the apparatus described in this paper. In Fig. 8 the extent to which the constant potential is modified is also shown. In this apparatus, we avoid the danger of the shunt method by reducing the charging rate to the depleted battery and by increasing the charging rate as we approach complete charge. We avoid the danger of the series or current method of regulating the charge to the storage-battery by giving the largest rate of current when the battery is depleted and by avoiding the too-high charging rate of the series method when the battery charge approaches completion. When the battery begins to gas, we also avoid the abrupt rise in voltage of the charging current. We also avoid the danger of continuously charging a battery at a normal rate long after the charge of the battery has been completed.



METHODS OF SPEED-CONTROL.

BY WILLIAM COOPER.

A consideration of the speed-control of shunt-wound direct current motors. Applications of this type of motor to the operation of machine-shop tools.

I have been requested to read a paper at this meeting on the subject of "Methods of Speed Control." As the field covered by this innocent little title in electrical business is so great and includes such a variety of apparatus in its ramifications, I was impressed with the impossibility of thoroughly covering the whole ground within the limits of such a paper, and have, therefore, concluded to confine my attention to very narrow limits to the consideration of the speed-control of the shunt-wound direct current motor. Further than this, I will confine myself to the individual application of this particular type of motor to the operation of machine-shop tools.

I realize that I may encroach upon the territory covered by a number of papers read at a recent meeting of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, but I trust I may be able to throw some additional light on the subject. In the discussion that followed the papers read at this meeting of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, there appeared to be some misunderstanding.

There seems to have been a difference of opinion, which was largely, I think, to be accounted for by different comprehensions of the point in question, namely: the constant h.p. rating of the motor, as spoken of. I hope that I may be able to make myself plain on this point, so that there will be no misunderstanding of the fact.

CONDITIONS TO BE FULFILLED.

The prime condition to be fulfilled in operating machine-shop tools is to keep the cutting-speed at the maximum at all times. This maximum speed is limited, of course, by the quality of the cutting tool, the kind of material being cut, and whether or not any extraneous means are employed to keep the tool from heating.

Nearly all ordinary machine-shop work may be classified under two heads; machining of cylindrical surfaces and of plain surfaces.

In considering the first class of operations, the piece being operated upon is usually rotated, and as a very small proportion of this work has but one diameter on each piece, there must, of necessity, be provided some way of changing the speed of rotation in order to keep the cutting-speed at the maximum. This condition is arrived at in ordinary machine shop practice on this class of work by using certain arrangements of change gears, and by belts on so-called cone-pulleys. While it is entirely possible to get a change in this manner of 10 per cent. per step, the complication resulting from the mass of gears and multiplication of steps on the cone-pulleys would not be permissible, to say nothing of the time lost in making the changes. As the result of years of practice, this system has developed into an arrangement where the changes are approximately 50 per cent. apart; that is to say, that each increment of increase would be 50 per cent., often being as much as 100 per cent. It is obvious that such an arrangement must be very wasteful of time where the diameter of the piece to be machined is slightly less than the nearest combination which would give the maximum cutting speed. The machine, therefore, must be run at slightly more than one-half or two-thirds of the maximum permissible cutting-speed, consuming, consequently, nearly 50 to 100 per cent. more time for a given operation than would otherwise be required.

Mr. F. O. Blackwell, in a paper read before the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, said, "The reduction effected by different sets of back-gears on machine-tools will be found to vary from 4 to 1 to 6 to 1. All tools can be arranged with 4 to 1 changes between back-gears without any difficulty. In many cases a single back-gear is sufficient for a tool. By putting a magnetic-clutch on this back-gear and making the electrical connections in the controller, it is possible to get a 6 to 1 variation electrically and without increasing the cost of the motor more than would be required for a 4 to 1 variation."

Mr. Chas. Day, in the discussion which followed the reading of

Mr. Blackwell's paper, said, "When attaching motors to old tools, such as lathes and drill presses, we must, as far as possible, adapt our speed range to the present gear ratios, in some cases by introducing additional gears, and in others without change to the machine. We have found that the gear ratios vary from 3 to 1 up to 15 to 1, depending on the size and character of the machine."

From the above we see that there is some difference in opinion as regards the range of the back-gears of ordinary machine-tools. As a matter of fact, the back-gear ratio of ordinary machine-tools varies from 3 to 1 up to 15 to 1, as stated by Mr. Day. There is also another fact which has not been touched upon and that is that the range of speeds given by the cones on a great many machine tools are not consistent with the ratio of the back gearing. That is to say, it is frequently found that the difference between the lowest speed with the back-gears out and the highest speed with the back-gears in is very much greater than the difference between two cone-speeds. Some machines have as much as 3 to 1 variation in speeds between these two conditions. The writer has in mind a case of a comparatively small sized boring-mill, made by a prominent manufacturer, in which the back-gear ratio was $12\frac{1}{2}$ to 1. In this particular case the difference between the lowest speed with the back-gears out and the highest speed with the back-gears in was a great deal more than the difference in the cone-speeds. However, in this case, if we were to allow that the best possible arrangement had been made, the average difference between speeds throughout the entire range of the machine would be about 1.9 to 1, the machine being equipped with a four-step cone.

SUBDIVISION OF SPEED RANGE.

It is obvious from above considerations that some arrangement must be introduced that will subdivide the speed changes to a greater extent. Many mechanical devices have been brought out for this purpose and some of them have come into quite extensive use; more particularly those where the gradation from one condition of speed to the next (as regulated by gears or driving belts) could be subdivided into any number of parts. While these devices fill the requirements of being able always to obtain the maximum cutting speed, the complication and cumbersomeness of the device is not desirable and has prevented its coming into general use.

A letter from Mr. E. H. Symington was read before the Central Railway Club, at their meeting at Buffalo, November 14th.

Mr. Symington, in speaking of electric-drive in general, very strongly recommended alternating current. In speaking of variable speed motors, he said: "With the advent of the perfected speed-changing devices, there is less necessity for having speed flexibility in the motor itself. However, where there are a quantity of traveling cranes and other variable speed apparatus, it is well to consider the advisability of a small direct current generating set for this purpose only."

METHODS OF SUBDIVIDING SPEED RANGE.

We are still waiting for the advent of the perfected mechanical speed-changing device. However, we must admit that we can not, practically, get a speed variation from an electric motor that will cover the entire working range of the average machine-shop tool. There are some tools in which this can be done, for instance, planers, slotters and machines of this character where the cutting speed of the tool is in constant relation to the work, regardless of its dimensions, and speed variation is only required for differences in material.

However, in that great class of tools in which the piece being operated upon is of circular form and the rotative speed varies directly with the diameter, a very wide range of rotating speeds is required. In this class of machinery it is practically impossible to cover the entire range by varying the speed of the driving motor.

Speed-control is obtained in nearly every case by a combination of mechanical and electrical means, the motor range and gear ratios depending upon the machine and the average variation in diameters and kind of material handled.

Mr. Blackwell made the further statement in his paper that "With the three-wire system and a 100 per cent. variation in the motors-speed by field-control, we can obtain a 4 to 1 total variation which, for general machine-shop work, is sufficient to cover a single operation on a given tool.

Any system of variable speeds to be applicable and to cover the ordinary working conditions must be able to cover all possible speeds within the range of the tool and not be confined to a single operation, as would be necessary to come within Mr. Blackwell's limits.

Since it is impracticable to get the entire range of speeds on the class of machinery mentioned directly from the motor, a compromise must be effected. We have in any given case a certain total range to cover in any given machine. Let us take for

example a 48-inch engine-lathe. Practice has shown that even with the best tool-steels at present obtainable, it is desirable and almost necessary to have a cutting speed as slow as 16 feet per minute. This, of course, determines one limit of the speed range, and is absolutely fixed, while the other limit of maximum speed at which the machine is to operate is not fixed, and is determined for each particular case by the probable minimum diameter to be machined. If two inches be assumed as the smallest diameter and a maximum cutting speed of 100 feet per minute, at this diameter the maximum revolutions will, therefore, be approximately 150 times the minimum. This, therefore, is the total range of speeds to be covered by the driving mechanism.

The question that next presents itself, and the one that cannot be determined by any hard and fast rule, is what portion of this range will be covered by the variations of the speed of the motor, if a motor be used, or what other equivalent system will give equally good results. The case cited in regard to the boring-mill is almost exactly the same as the one under consideration. As stated, the builder solved the problem by using cone-pulleys and one set of gears. It must be admitted, however, that this solution was very crude. On the other hand, the question is: How many different speeds should be provided within this range and how will they be obtained? As stated, it is impracticable and well-nigh impossible to cover this range entirely by varying the speed of the driving motor.

The next step, consequently, is to use one set of back-gears. This will call for back-gears to be approximately $12\frac{1}{2}$ to 1 ratio; therefore, the limit of speed variation on the motor will be $12\frac{1}{2}$ to 1. The next combination available is to use two sets of back-gears, which shall have equal ratios and which shall gear into each other. In this case the variation of the motor speed will be as the cube-root of the total variation, or approximately as 5.5 to 1.

This same line of reasoning may be followed, duplicating the gearing indefinitely, until the variations in speed are entirely taken care of in the gearing. This brings us to the future perfected mechanical speed changing device, which has not yet made its advent.

ADVANTAGES OF SUBDIVIDING SPEED RANGE.

The question is often asked: "What advantages are to be derived from driving machine-shop tools independently by electric motors?" The answer to this is, that the principal

advantage is in the ability to obtain any number of different speeds on the tool, thereby being able to work up to the maximum output at all times.

Mr. L. R. Pomeroy, in a paper read before the Central Railway Club, in Buffalo, November 14th last, quoted a celebrated authority, without naming the authority, as follows: "Where we have to decide whether we shall install one large motor or a number of small ones, I would give preference to the small motors down to a limit of 5 h.p. for light machines and 10 h.p. for heavy machines; this for cases in which the problem is one of distribution only. Where the introduction of motors would have any effect on the product, I would dismiss entirely the question of power and decide solely with regard to the convenience of operation afforded, and would not hesitate to put in the very smallest motors, mounted upon any kind of machinery, notwithstanding their greater cost and lower efficiency, if they even to but a slight degree increase the product of the labor of the shop. Gains in this direction cause other gains to sink into insignificance."

Mr. Blackwell voiced the same sentiment, as follows: "The most important consideration in the electric driving of machine-tools is to make the control of the tool as convenient as possible and arrange the system so as to permit small changes in speed, and consequently be able always to drive the tool at its highest possible speed and greatest output."

Another question that usually follows is: "But the tools in this shop are not designed to stand the higher speeds that the modern tool-steels will permit, therefore, it is not possible to work them up to the maximum." A reply to this is, that if the machine will not stand the strains brought about by high-cutting speed of the modern tool-steel, they still have their maximum, and there is just as good reason for working these tools to a maximum as any other tool to its maximum, although the maximum of these tools may be determined by a different factor.

We might state, however, that there is no reason why a machine-tool that is adapted to do a certain work, should not do this work at two or three times the speed. The reason for this seems obvious in the fact that the strains on a machine are due entirely to the torque required to make a given cut. With this given cut, the speed may be increased three or four times without producing any greater strains on the machine itself, because the torque remains constant. However, the h.p. will increase

directly in proportion as the increase in speed; and right here we have a factor that limits the ordinary belted machine-tool—the belts will not pull the load. For instance, suppose that we have a given machine running with a belt on the largest step of the cone-pulley on the machine, and taking a certain cut; assume the cutting speed be twenty feet a minute. If it is desired to increase this cutting speed to, say, eighty feet per minute, it is found necessary to put the belt on the smallest step on the cone. We at once encounter the difficulty that the belt will not begin to pull the cut. This is also true of the various mechanical speed-changing devices that have been introduced. Thus it will be seen that machine-tools that were designed on the lines of the cutting speed of twenty feet per minute are not adapted at all to cutting speeds of eighty feet per minute. However, they are not eliminated by the strength of the tool, *but by the pulling power*. Under these conditions, it is only necessary to increase the pulling power of this machine to make it do four times the actual work that it formerly did. Here again is where the electric motor gets another big advantage.

Thus it is seen there are two good reasons (and there are many more) for equipping machine-shop tools with electric-drive, namely: first, the ability at all times to run the tool at its maximum cutting speed; secondly, ability to supply the necessary pulling power. Among the other numerous advantages in equipping machine-shop tools with electric drive might be mentioned the ability of placing machines in any position at will, making them as it were portable machines; absence of belts from the shop, with their accompanying obstruction to light and accumulation of dirt.

SELECTION OF MOTORS.

In equipping machine-shop tools with electric-drive, there are many points to be considered in the selection of suitable motors. The first consideration which directly affects the cost of installation, is the highest permissible speed at which the motor can be operated.

After determining this point, the next point is its lowest speed. Then we have the range through which the motor is to operate, and after determining this range, the next question is the determination of the method of obtaining this range of speed, if it is desired to get different speeds by varying the speed of the motor. When using the so-called variable-speed motor, there are two methods available which practice has shown to be good:

one by varying the field strength, the voltage on the armature remaining constant; the other by varying the voltage on the armature, the field strength remaining constant. The method which first presents itself is, varying the field strength of the motor. This is a very simple and effective way, but it is accompanied by the disadvantage of requiring a larger motor than the other method. For instance, if a speed range of 2 to 1 is required, and the motor is run from a source of constant potential, the motor would require to be twice as large as a motor giving the same range by varying the voltage on its armature. In other words, a motor that will give 1 h.p. at 2,000 r.p.m. maximum with a weakened field, and would also be capable of running a 1,000 r.p.m. on a full field, would give 2 h.p. at 1,000 r.p.m. This motor would, of course, if designed to run at full field strength at 2,000 r.p.m., give 4 h.p.

In the second method—that of varying the voltage on the armature, the field remaining constant—the size of motor required for a given range can be compared as follows: Assume as above that a speed range of 2 to 1 is required and the speed will be varied by changing the voltage on the armature. One h.p. being required at all speeds as above, and 1,000 r.p.m. being the minimum and 2,000 r.p.m. being the maximum, a motor that would give 1 h.p. at 1,000 r.p.m. on full field would give 2 h.p. at 2,000 r.p.m. with the same field strength, but with double the voltage on the armature. Thus it is seen that in one method the motor has minimum h.p. at its maximum speed, while in the other, the motor has minimum h.p. at minimum speed.

Mr. L. R. Pomeroy, in his paper before the Central Railway Club, spoke of interposing armature resistance in circuit with an electric motor for various speeds. He said in that connection: "While it is obviously not advisable to presume in using the full range of such speed variation continuously, yet in conjunction with step-cones and back-gears, any intermediate speed between the cones or gears can be exactly met by the introduction of very slight amount of resistance or electrical regulation, and under such conditions such variation is feasible and practicable. This represents the cheapest form of utilizing motor speed-variation from a standpoint of first cost. Next in point of cost is the use of a special type of motor, giving 100 per cent. field regulation. By this type of motor the varying requirements of almost any tool can be met at a slightly increased cost over constant speed or standard motors. This, in the writer's judgment, is a rational

method of meeting the case, as the range of speed is liberal, and its cost moderate. A motor of ordinary design will not permit of any considerable field weakening without deleterious sparking at the commutator, but with a special motor having small armature reaction, a variation in speed of 2 to 1 can readily be obtained; and when delivering a constant horse-power, the current will be approximately the same at all speeds, because the potential across the armature terminals is always the same. As the field current of a motor is only a small fraction of the total current, the efficiency of this method of control is practically the same at minimum and maximum speeds and allows the use of a much smaller controller and renders it possible to get a greater number of running speeds than can be economically arranged for with any other control."

He says that a motor with 100 per cent. field regulation, giving a speed range of 2 to 1, costs but little more than a standard constant-speed motor to do the same work. As a matter of fact, this motor is four times as large as a constant-speed motor to do the same work at the maximum speed. Furthermore, this motor with 100 per cent. field regulation, if supplied with different voltages across its armature terminals, can be made to give another 100 per cent. speed variation by voltage regulation, thereby yielding a total speed variation of 4 to 1. Mr. Pomeroy says the speed variation of 2 to 1 is liberal, but if the same motor can be made to give, without additional cost, speed variation of 4 to 1, there would seem to be no reason why it should not be done and it would be more than liberal. This same conclusion was arrived at by Mr. Blackwell in his paper. He said:

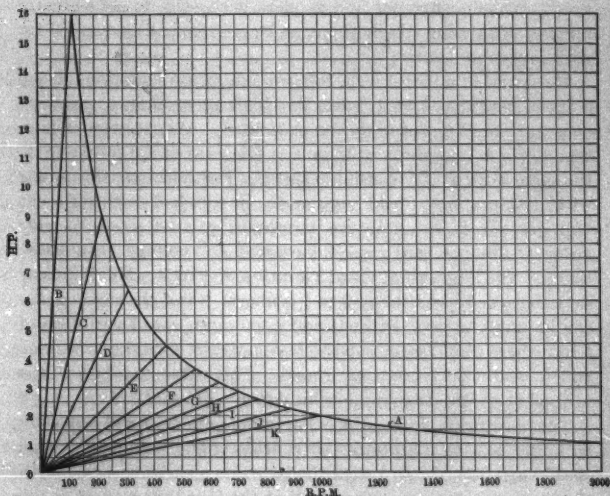
"In conclusion, I would say that in my opinion it will generally be found best to use motors with field-control, allowing a total speed variation of 2 to 1 with the two-wire system or 4 to 1 with the three-wire system, believing that the four-wire system is too expensive for general application if the plants employing it are properly designed and equipped with large enough electrical apparatus."

It is seen from the foregoing that there is a great desire to obtain as wide a range of speed variation in the motor as possible. What one person may consider sufficient in this respect, would be considered entirely insufficient by another. The speed range through which a motor is to be operated for any given case is governed by a number of different considerations. The additional cost of the motor for increased range of speed variation

will be offset by a saving in additional gearing and the ease of manipulation. The consideration of the last point is all important. The time spent in juggling the gearing of any given machine will accumulate during the entire life of the machine, and means a constant expense which may, under some circumstances, be much greater than the interest on an investment by which it would be eliminated in considering the difference in size and cost of motors to perform different functions.

DETERMINATION OF MINIMUM SIZE MOTOR.

If it is desired to have a motor that will give a speed variation



No. 1. Horse Power Curve-Multiple Voltage and Field Regulation.

of 4 to 1 by shunt-field resistance, instead of 2 to 1 as in the former case, the motor would be four times as large (instead of twice as large as in that case) as a variable voltage motor to do the same work. Thus, it is seen that the limitation of shunt-field control is soon reached. However, a combination of shunt-field control and multi-voltage circuits gives an arrangement by which a comparatively wide range of speeds can be obtained without the motors being of excessive size. This may be readily understood by referring to curve sheet attached. Fig. 1. Curve

"A" represents change in h.p. of any motor when running on a weakened field. This might be called a diminution of h.p. curve. For instance, on the curve we see that a motor that will give 5 h.p. at 400 r.p.m. gives 1 h.p. at 2,000. From this curve we can determine the minimum size motor that will be required for any given case, using either shunt-field regulation entirely, or combining shunt field-regulation and multi-voltage, or multi-voltage entirely.

[CONTRIBUTED AFTER ADJOURNMENT OF THE FEBRUARY 27TH MEETING, BY J. R. BIBBINS.]

Considering the subject of train lighting by electricity in its broadest aspect, it is necessary to reduce all methods to an unbiased competitive level, determined almost entirely by commercial considerations of: 1. First cost. 2. Cost of operation and maintenance. 3. Results to be obtained. There is no doubt but that the multiple-unit or axle-light system is the most attractive of the several methods advanced for train lighting, and the ingenuity displayed in some of the present apparatus worthy of highest commendation, by reason of the almost insuperable difficulties encountered; but the question of cost and results obtained are nevertheless paramount in the mind of the unbiased purchaser.

The following comparative table cites briefly the advantages and disadvantages of the two prevailing systems.

ELECTRIC TRAIN LIGHTING.

Multiple-Unit. <i>Axle Lighting Outfit.</i>	Single-Unit. <i>Engine-Generator Unit.</i>
Advantages: - Independent car illumination. - Power obtained from locomotive without intermediary connections. - No attendance required en route. Disadvantages: - Erratic current generation. - Commutation difficulties. - Small and inefficient units. - Increased hysteresis loss at high speeds. - Reversal in rotation. - Storage batteries essential. - Inefficient power transformation. - Apparatus exposed and subject to jar. - High depreciation and maintenance. - High initial investment.	Advantages: - Concentration of many small units under one control. - Standard and efficient apparatus. - Uniform rotation and voltage. - Adequate potential regulation. - Absence of mechanical complexity. - Apparatus protected and in full view. - Higher gross efficiency. - Small total weight. - Low initial investment. - Minimum depreciation and maintenance. Disadvantages: - Valuable space consumed. - Flexible conductor between cars necessary. - Attendance required en route. - Storage batteries required during disconnection of locomotives.

In directing attention to the single-unit system, it is not the intention to advocate any particular class of apparatus for ful-

filling the required conditions, but to emphasize the many important and vital features of the system in distinction to those of other systems so ably and exclusively championed at the last meeting of the INSTITUTE.

The single unit system is at the present time in successful operation upon a number of important roads running fast limited service of the highest character. The usual equipment consists of a 25 or 30 h.p. vertical two-cylinder engine, direct connected to a $17\frac{1}{2}$ or 20 k.w., 125-volt d.c. multipolar generator, both mounted upon a common bed-plate, and installed in a small compartment in the forward part of the baggage car, directly over the forward truck. The engine receives steam at 100 lbs. pressure from the locomotive through a flexible hose connection. It exhausts through the roof, a suitable muffler being inserted for retaining oil and condensation and deadening the exhaust. The few meters, switches and simple wiring required are mounted upon the side of the car. The train line between cars is established by means of a flexible cable with special lugs, which may be quickly connected during the make-up of the train. Storage batteries may or may not be employed, according to the nature of the train service, and are not essential to the operation of the entire electrical equipment. It is customary, however, to insert a small battery under the baggage car for furnishing current during change of locomotives. This procedure may extend to other parts of the train, such as dining cars and sleepers, which are to be disconnected from the train at stations en route.

The generating outfit weighs approximately 7,000 lbs., thus averaging but 1,000 lbs. per car in a seven-car train. This is but 30 to 60 per cent. of the weight of present multiple-unit systems per car. The unit stands 5 ft. high over all, and requires 25 sq. ft. of floor space. It may be conveniently installed crosswise of the car, in a compartment 6 ft. long, thus consuming from 9 to 10 per cent. of the baggage car room; or it may be left unhoused, when this floor space may be somewhat encroached upon. The steam consumption of the engine averages 35 lbs. per i.h.p. hour by actual test and the efficiency of the generator is 90 per cent. at full load. Assuming the combined efficiency at 76 per cent., the net steam consumption at the locomotive approximates 45 8/10 lbs. per h.p., delivered at the generator terminals.

For purposes of incidental comparison with the multiple-unit or axle-lighting system, we may assume the steam consumption of an express locomotive to be 22 lbs. per i.h.p., its mechanical efficiency 85 per cent., and the corresponding figures of efficiency of car truck, mechanical drive, and small generator 90 per cent., 75 per cent. and 83 per cent. respectively. Upon this basis, the steam consumption of the multiple-unit system becomes 46.3 lbs. at the boiler. These latter figures are of course only tentative, but may serve partially to refute the popular argument that this system derives its power directly from the locomotive, with no appreciable loss, by calling attention to the fact that

there are six distinct transformations of energy involved, as against two in the single unit system. The figure 75 per cent. would probably be exceeded in properly designed gear transmission, but not in belt transmission, and especially not in apparatus involving slippage of friction discs, rollers or belts. According to present quotations, which may not be given here, the cost of a single-unit equipment ranges from 15 to 25 per cent. of that of a multiple-unit outfit, for a seven-coach train, together with the necessary batteries. The introduction of an auxiliary battery in the former system reduces this difference proportionately.

Maintenance and depreciation of the single-unit is evidently a much less important factor in cost of operation than that of the multiple-unit system. On one railroad, one of the single units has run successfully for $5\frac{1}{2}$ years, averaging 12 hours per trip, while the particular type of engine used has to its credit a record run of 13 months, 8 days without stop, and a repair account during 12 years of operation amounting to 2 per cent. per annum of the first cost. The attendance required upon one of the roads above cited is furnished by the baggage-man, who receives \$1.52 per day extra wages for the service, amounting to 22c. per car day or about \$80 per car year. The cost of supplies and maintenance for the generating unit seldom exceeds \$25 per year. The entire cost of operation, exclusive of the battery, thus totals considerably under \$100 per car year. May it not be barely possible that the single-unit system, with all its faults, will successfully compete with its ingenious rivals on the score of reliability, durability and non-complexity, as well as that of low cost of investment and maintenance?

DISCUSSION AT PITTSBURG, APRIL 9, 1903.

Programme.

The meeting was called to order by Chairman P. M. Lincoln.

1. Introductory Remarks.—President C. F. Scott.
2. "Mechanical Specifications for Proposed Standard Insulator Pin," by Ralph D. Mershon, read by W. K. Dunlap.
3. "The Testing of Insulators," by F. O. Blackwell, read by C. E. Skinner.
4. "Transposition and Relative Location of Power and Telephone Wires," by P. M. Lincoln.
5. "Burning of Wooden Pins on High-Tension Transmission Lines," by C. C. Chesney, read by E. M. Tingley.

The discussion was participated in by C. E. Skinner, S. P. Grace, P. M. Lincoln, H. Etheridge, C. W. Rice, Mr. Bedell, P. H. Thomas, B. Frankenfield, J. S. Peck and President C. F. Scott.

MR. SKINNER:—I have always been under the impression that for glass insulators a potash glass would give better results than a lead glass. This impression has not been thoroughly proved by test. Mr. Blackwell says that the striking distance of a given e.m.f. is greater at high altitudes than at low altitudes. If the striking distance is to be used by the INSTITUTE as a measure of the e.m.f., some figures should be obtained showing the variation of striking distances with the variation in the height of the barometer.

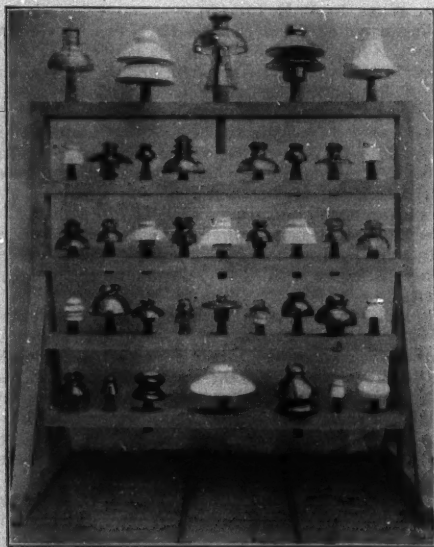
In early high tension work the question of surface leakage over the insulator was considered of very great importance, and many of the earlier designs of insulators included an oil cup underneath to give a higher surface resistance. As far as I am aware, this construction has not been used on any of the long-distance transmission lines in the United States, and later practice has proved that such a device is entirely unnecessary. It is objectionable because it is soon filled with foreign substances and defeats the object for which it was designed.

The method of regulating the voltage of the testing transformer should receive consideration. There are three methods which have been followed, viz: first, by varying the field of the generator; secondly, by the use of a resistance in series with the low-tension side of the testing transformer; thirdly, by varying the voltage on the low-tension side of the transformer by means of a regulator dial connected to a suitable regulating transformer with a number of taps brought out from its secondary winding.

The first method can be used only where a generator is provided exclusively for this work. In the second method a water rheostat is usually employed. This gives a very smooth variation in e.m.f., and while unwieldy and requiring constant attention during the test, it is capable of giving very good results. The third method requires that the voltage on the high-tension side be changed by comparatively small steps, which may be done with proper regulating dials without opening the circuit. Steps

even as great as 5 per cent. are not considered particularly harmful in the testing of insulators.

I am pleased to be able to show you an exhibit of insulators intended for high-tension work. This exhibit is not complete by any means, but shows a number of types which are in use at the present time. Most of these insulators have been given a test which may be briefly described as follows: the insulators were placed on the standard size pin, the pin being wrapped with tin-



foil. A photograph of the insulators (Fig. 1) as they appeared on the testing rack after a snow storm is submitted as part of this discussion. The test was made by applying the high potential from a testing transformer, the voltage of which was regulated by means of a regulator dial giving very small steps. The testing voltage was applied between a "tie" made in the ordinary manner and the tin-foil coating of the pin and the test was made under different weather conditions. The break-down test was repeated at intervals for a period of some months, beginning about the middle of February and ending about the first of July.

In no instance did a break-down occur through the insulator

itself, the break in every case being over the surface. The maximum testing voltage available was approximately 90,000 volts. In some instances, when the insulator was dry, no break-down over the surface could be obtained. The following are the results of tests on certain characteristic insulators, as shown in the accompanying photographs. (Fig. 2 and Fig. 3).

No. 1—Porcelain, brown glaze:

Diameter at base	10"
Height	8 $\frac{1}{4}$ "
Surface distance from wire to pin.....	22 $\frac{1}{4}$ "
Shortest breaking distance.....	12"

When dry and clean, stood	91,000 volts.
During heavy, dry-snow storm, stood.....	90,000 "
During moderate rain storm, broke down at	86,400 "
When covered with ice and snow, broke down at.....	52,200 "
When dry, stood for $\frac{1}{2}$ hr.	71,500 "



FIG. 1.

During the last test the snow was piled on the cross-arm almost to the lower petticoat.

No. 2—Porcelain, brown glaze:

Diameter at base	7 $\frac{1}{2}$ "
Height	6 $\frac{1}{4}$ "
Surface distance from wire to pin.....	13 $\frac{1}{4}$ "
Shortest breaking distance.....	9 $\frac{1}{8}$ "

When dry and clean, stood	92,000 volts.
During dry-snow storm, broke down at	87,300 "
Covered with wet snow, broke down at.....	62,100 "
During moderate rain storm, broke down at	68,400 "
When dry, stood for $\frac{1}{2}$ hour	66,000 "

No. 3—Porcelain, brown glaze:

Diameter at base	6 $\frac{1}{4}$ "
Height	4 $\frac{1}{2}$ "
Surface distance from wire to pin.....	13"
Shortest breaking distance.....	7 $\frac{1}{4}$ "

When dry and clean, stood	91,000	volts.
During dry-snow storm, broke down at	78,750	"
During moderate rain storm, broke down at	48,600	"
Covered with wet snow, broke down at	54,000	"
When dry, stood for $\frac{1}{2}$ hour	64,400	"

No. 4—Porcelain, brown glaze:

Diameter at base	6 $\frac{1}{2}$ "
Height	4 $\frac{1}{4}$ "
Surface distance from wire to pin	8"
Shortest breaking distance	6 $\frac{1}{8}$ "

When dry and clean, broke down at	73,800	volts.
During dry-snow storm, broke down at	78,750	"
During moderate rain storm, broke down at	53,400	"
When covered with wet snow, broke down at	52,350	"
When dry, stood for $\frac{1}{2}$ hour	55,000	"

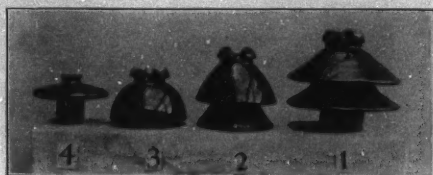


FIG. 2.

No. 5—Porcelain, white glaze:

Diameter at base	6"
Height	4"
Surface distance from wire to pin	11 $\frac{1}{4}$ "
Shortest breaking distance	6 $\frac{1}{4}$ "

When dry and clean, broke down at	74,700	volts.
During dry-snow storm, broke down at	70,200	"
During moderate rain storm, broke down at	70,400	"
When covered with wet snow, broke down at	42,800	"
When dry, stood for $\frac{1}{2}$ hour	52,500	"

No. 7—Glass:

Diameter at base	7"
Height	6"
Surface distance from wire to pin	15 $\frac{1}{4}$ "
Shortest breaking distance	7 $\frac{1}{4}$ "

When dry and clean, broke down at	74,700 volts
During dry-snow storm, broke down at	73,800 "
During moderate rain storm, broke down at	52,800 "
When covered with wet snow, broke down at	51,100 "
When dry, stood for $\frac{1}{2}$ hour	55,000 "

No. 8—Glass:

Diameter at base	7 $\frac{1}{2}$ "
Height	5 $\frac{1}{2}$ "
Surface distance from wire to pin	12"
Shortest breaking distance	7 $\frac{3}{8}$ "

When dry and clean, stood	91,800 volts.
During dry-snow storm, broke down at	87,300 "
During moderate rain storm, broke down at	62,700 "
When covered with wet snow, broke down at	58,800 "
When dry, stood for $\frac{1}{2}$ hour	63,000 "



FIG. 3.

After the insulators had been up for some months and were well coated with dirt and soot they were given a time test on a dry day. The time test was made by applying $\frac{1}{2}$ of the maximum test voltage for $\frac{1}{2}$ hour. The figures are given under the last heading in each set of tests. All the insulators stood this test without any evidence of trouble, except a considerable static discharge over some of those with the thinner sections.

I think that the burning of pins is caused in many cases by the static discharges which appear at the wire and at the pin. If the material can be made thick enough, so that these discharges will not appear, the burning of the pins will probably be decreased to a very considerable extent. I think the final solution of the pin-burning question would be to discard the wooden pin altogether and substitute a metal pin properly cushioned to take undue local strains off the insulator itself.

Mr. Grace called attention to the trouble which the telephone companies have had from electrostatic effects. As fast as one difficulty has been overcome another is encountered, to overcome which new methods must be devised.

The system of transposing wires in order to overcome the induc-

tive effects of one circuit upon another was devised by the telephone engineers and first used on the long-distance circuit between New York and Philadelphia.

The necessity of keeping telephone circuits in absolute balance was mentioned and a number of instances were given where an extremely small amount of unbalancing was sufficient to produce serious disturbances.

Mr. Grace said that Mr. Lincoln's paper treated only of telephone circuits upon the same poles with the power circuit, whereas in commercial telephone service there were many thousands of circuits and it is manifestly impossible to insulate them to so high a degree as where there is but a single telephone circuit. He thought that representatives from the telegraph, telephone, and power-transmission companies should convene and devise suitable means for crossing the different lines where it is necessary.

Mr. Frankenfield commented on the effect of grounding the neutral point of a transmission system. He also commented on the burning of insulator pins.

Mr. Bedell recounted his experiences while testing insulators. His general conclusions were that the question of dielectric strength of glass and porcelain had been satisfactorily settled, as insulators almost never broke through the dielectric but over the surface.

Mr. Lincoln spoke as follows: One interesting statement made by Mr. Grace was that the arc circuits of the "tub system," so-called, is one of the hardest things the telephone people have to contend with. This sustains one of the arguments made in my discussion—that the static induction gives more trouble than the electromagnetic. The conductor in such an arc system is apt to be at a considerable difference of potential from the earth, and usually in the arc circuit the equal and opposite potential is not present to neutralize its effect as is the case with a statically balanced transmission line. I should imagine the arc circuit would be harder to contend with, though its potential is not so high as that of the usual accompanying transmission line. I should like to have Mr. Grace explain what he calls a retardation coil.

MR. GRACE:—It is an electric choke-coil and we speak of it as a retardation coil.

MR. ETHERIDGE:—I wish to refer particularly to the necessity of studying every detail of a transmission line, with the view of applying the latest and best possible forms of construction to insure the stability of the medium between the step-up and the distant step-down transformer.

Estimates are carefully prepared and the best engineering skill applied to the erection of central plants and substations, but the transmission line, which is subjected to the worst possible mechanical and electrical strains and conditions, is, generally speaking, the least considered and provided for.

The building of a transmission line is purely a mechanical problem, and must receive as much care and skill as the remainder of the system, if stability of action—which is the keynote of engineering success—is to characterize its operation.

The average transmission line suffers from comparison with the modern power house and substation equipment, and as the system is strongest only at its weakest point greater care and skill must be applied to that part of the system which is found outside the buildings, where the most adverse mechanical and electrical conditions are encountered.

Our worst experience in the operation of transmission lines has been due to mechanical weakness of some of the details of the line; particularly wooden pins and faulty mechanical design of some of the insulators. The angles and guys have also given us trouble on account of their inadequacy for the heavy strains put upon them. I can safely say that electrical troubles of our line have been entirely absent. To overcome the mechanical troubles of pins and insulators, we were compelled to design and adopt a form of pin and insulator a sample of which you will find on exhibition here this evening, and in which the greatest mechanical strength and other features are embodied.

Having solved the question of weak pins and insulators, we next turned our attention to the angles of our line and to proper guying with the result of developing a rigid and successful form of construction. In these angles we have adopted poles of 13" and 14" tops, 4"×5" double oak cross-arms with $\frac{3}{4}$ " ring bolts and washers. The braces are $\frac{3}{4}$ "×1 $\frac{1}{2}$ " and 30" long, bolted with $\frac{1}{2}$ "× $\frac{3}{4}$ " bolts and washers in cross-arms and through the poles, respectively. The cross-arms are bolted together with $\frac{3}{4}$ " bolts and washers with the usual making-up piece between them. The pin-holes in the cross-arms are 1 $\frac{1}{2}$ " diameter, thereby maintaining the strength of the arm. Great care is also exercised in placing the arms diagonally across the angle so as equally to distribute the strain on each pin and insulator.

The "wet-rot" of our poles at the butt received our next attention, as it became evident to us that in seven to ten years our entire pole line would have to be rebuilt; a feat fraught with great danger, expense, and interruption in our service, if it did not threaten absolute shut-down.

I developed and adopted a remedy against this "wet-rot" of our poles. This consisted in cementing about one-third of the pole flush to and extending about 3" above the ground line, and then placing a fillet of pitch, asphaltum, or some such moisture-proof material to a depth of about 8" between the pole and cement of the ground-line, so as to separate or seal the pole from contact with the moisture in the earth at the ground-line. This very effectually prevents "wet-rot" of wooden poles and oxidation of steel poles at the ground-line. The additional expense of preparing and treating our poles in this manner is very trifling compared with the great expense of replacing them.

Mr. Scott has well said that "development of detail in electrical machinery has made possible very reliable forms of apparatus," and the same reasoning and skill must be applied to our transmission line before the ideal electrical transmission will be attained.

At the request of Mr. Lincoln I will explain the features of the pin and insulator which it was my pleasure to develop. It consists of a malleable iron tube $1\frac{1}{4}$ " outside diameter and $1\frac{1}{8}$ " inside diameter. On the outside of this tube-pin is cast a shoulder on which it rests when placed in the cross-arm. To lock this tube-pin to the cross-arm a flat high-carbon steel spring—on each end of which if formed a gib—is driven through the pin until the bottom end springs out over the bottom end of the pin and cross-arm.

The insulator, which has a plain hole to receive the pin, and a recess at the bottom of the hole to receive the top gib of the spring, is then forced down over the pin until the top gib springs out into the recess in the insulator. This combination very securely locks the insulator to the pin and the pin to the cross-arm; to unlock, place a screw driver between the lower gib and the pin, force the gib back and drive the spring out through the pin again.

The features of this form of pin and insulator are:

- (1) Simplicity and durability.
- (2) The presenting of a plain surface, so as equally to distribute the wire pressure between the contact or bearing surface of the pin and insulator.
- (3) Secure locking to the cross-arm and ease of removal therefrom.
- (4) Freedom of insulator to turn in either direction on pin and act as a sheave to the wire when used in angles.
- (5) Looseness of the insulator on the pin, avoiding the breaking of insulators from expansion or contraction.
- (6) Locking the insulator to the pin and cross-arm, yet preserving looseness and freedom on the pin.
- (7) The placing of the wire groove in insulator so as to relieve the insulator from any wire leverage and any stress other than one tending to crush the glass or porcelain, etc.

Our telephone system is erected on the same poles and is bracketed about 5 feet below the lower cross-arm. These lines are absolutely quiet; the electromagnetic and electrostatic influence being overcome by using twisted pairs of wires.

(For illustrations of pins described by Mr. Etheridge, see New York Discussion, March 27th, 1903.)

MR. THOMAS:—As Mr. Etheridge has said, the greatest practical difficulty in the operation of high-tension transmission lines arises from mechanical defects rather than electrical ones. Broken pins, broken cross-arms, broken insulators and injuries to the line from external causes vastly outnumber the electrical failures. As is easily seen, the pin is the weakest mechanical link

of the system and when of wood of good insulating quality, it is liable to be weak. I wish to call your attention to a plant installing at Mexico, which marks an improvement in pole-line construction from a mechanical point of view. Five hundred foot spans are used, which is approximately five times the length of span usually employed elsewhere, and instead of the usual wooden poles, there are built-up steel towers. The cross-arms and pins, I understand, are of steel, the insulators of porcelain. This construction if well designed assures excellent mechanical qualities, and should be watched with great interest. On account of the small number of poles a much larger pin can be economically used for each one.

Ground wires, such as Mr. Lincoln has recommended for protecting the telephone circuit on a transmission line, might be used on telephone trunk lines, parallelling transmission lines, close to the telephone line but between it and the power line. It is probable that a very great reduction of the static induction from the high tension would be obtained by the use of even a few grounded wires as a screen. I make this suggestion to Mr. Grace.

The question of lightning arresters for telephones, and the fact that they are ordinarily adjusted to discharge at about 300 volts, suggests the mention of a point in the operation on the telephone lines and power circuits by which in some cases the service has been very much improved. In a good many power transmission systems where the standard telephone arrester is used on the telephone circuit, it has been found that there is at almost all times a sufficient unbalance of the high-tension voltage so that a frequent discharge to ground occurs over these arresters, the result being a leaky line and more or less continuous rattle of the telephone. The construction of an air gap in place of the lightning arrester very much reduces the number of such discharges to ground and entirely prevents the high resistance leak which usually occurs in a telephone arrester. The result is a great improvement in the speech.

Some of the telephone engineers here have referred to the problem of making satisfactory cross-overs between two lines. From their point of view the transmission line is a telephone line. The problem is broader, however, and should include the crossing of two high-tension lines. The National Board of Fire Underwriters has recently adopted recommendations as to methods of such cross-overs. They suggest three methods, but preference is expressed for crossing by means of a pole common to the two lines. This pole should, of course, have extra strength and extra height, the highest-tension line being carried at the top. Extra long cross-arms are used and the difference in the height of the poles of the upper and lower lines will ordinarily prevent anything which falls from the upper wire to the ground from touching the lower wires. To prevent a wire breaking at the farther end of one of the adjacent spans of the higher line from falling against the lower line, a guard wire mounted on the line, prefer-

ably insulated, should be installed outside of the extreme wire of the lower line.

A wooden pin is burned by leakage current because either its resistance is too high to transmit the current without excessive heating, or because its insulation is too low to prevent the leakage. In most cases either a better or a worse pin would not be injured. A comparatively few per cent. improvement of the pin would in many cases be sufficient to prevent destructive heating. Therefore, the method used by Mr. Gerry for protecting the pin which has been put in first-class condition, from moisture and dirt, by means of a sleeve is an excellent one, since it will certainly give a considerable protection to the pin and render it oftentimes safe where an unprotected pin will conduct enough to become charred. Mr. Gerry's freedom from trouble from burned pin referred to by Mr. Skinner is probably due to the fact that his pins are protected by glass sleeves, but also it must be admitted that his line is yet young and the climatic conditions are not severe. San Francisco is probably one of the hardest places in the country on pins and I think no wooden pins would be able to stand indefinitely there without burning.

Since the difficulty of operating a telephone line on an unbalanced high-tension power line results from the tendency for a high-potential to ground—equally on both telephone wires, provided the telephone line be transposed—it may be possible to solve the difficulty by insulating the telephone line highly and allowing it to assume its neutral potential, and transmitting the speech through a raising and lowering transformer at either end. The low-tension windings of these transformers may then be grounded, and with good insulation between the high and low-tension windings the operation may be made very secure.

I would like to ask Mr. Grace whether it is feasible to use such a transformer for transmitting telephonic speech.

The same sort of result might be attained by the use of condensers, two in series with middle grounded, connected between the wires of the insulated telephone line, the telephone receiver or transmitter being connected between the ground plates of the two condensers. For this purpose it would probably be necessary to use a double winding, either on telephone-spool or choke-coil, so that the charging current to the condensers would have its effect on the telephone circuit neutralized.

MR. GRACE:—The use of the transformer, as suggested by Mr. Thomas, is feasible.

MR. PECK:—In his paper on the testing of insulators, Mr. Blackwell says: "There should be but one transformer used to step up to the highest potential required and its reactance should be as low as possible. A number of transformers in series is particularly bad, as it gives poor regulation and leads to great uncertainty as to the actual potential to which an insulator is being subjected."

In the discussion at New York, Mr. Mershon called attention to

the advantages obtained by the use of a number of transformers in series for obtaining a high voltage, saying that it was possible to obtain such a series having good regulation; and a great point in its favor was that in case of accident to one transformer of a series, the remaining transformers could be used to deliver a somewhat lower potential.

There is an idea more or less generally prevalent that it is possible to obtain without danger a high voltage by connecting in series a number of transformers wound and insulated for a low voltage, as long as cases are insulated from each other and from the ground. Fig. 1 shows such an arrangement, where three 10,000 volt transformers are connected with high-tension winding in series for giving 30,000 volts.

It will be at once seen that there is a strain of 30,000 volts at the two points (A) and (B). The normal strain for one transformer is 10,000 volts, so that the outside transformers of the series are subjected to three times normal voltage strain be-

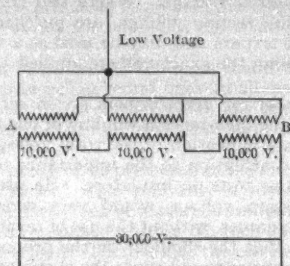


Fig. 1.

tween primary and secondary windings. If there were ten 10,000 volt transformers connected in series for 100,000 volts, the strain across the outer transformers of the series would be 100,000 volts, ten times normal.

In the operation of a number of transformers in series for obtaining a high voltage, there are much more severe internal strains introduced than where the transformers are used for a low voltage. This strain occurs between turns and layers and comes principally on the outside coils of the outside transformers of the series. In designing transformers for connecting in series it is therefore necessary to insulate each transformer not only between high-tension and low-tension windings, but between turns and layers of each winding, in the same manner that would be required were the transformer to furnish alone the full voltage of the series.

On account of the large amount of insulating material demanded between high-tension and low-tension windings, it is

extremely difficult to make these transformers with good regulation on inductive loads.

The cost of small transformers for very high-voltage work is, within certain limits, almost independent of the capacity; so the difference in cost between one transformer of the series and a single transformer wound for the total capacity would be very small.

It is true that the outer transformers of a series may be more heavily insulated than the others, making a reduction in cost on the inside transformers, but this affects the interchangeability of the transformers and the extra cost of manufacturing transformers which differ slightly from each other will probably more than counterbalance the saving in insulation.

The question of a spare unit is undoubtedly of importance, but I believe that in general it will be cheaper to purchase two transformers, each wound for the full testing voltage, than to buy a large number of transformers which are to be connected in series for giving the desired voltage. Where two transformers, each wound for the full testing voltage, are purchased, one will of course be held as a spare and may be used as a voltmeter transformer for obtaining the exact voltage applied to the apparatus on test.

When a number of transformers are in series, the voltage measured across the high-tension winding of one transformer will not be an accurate indication of the total voltage on the series.

Mr. Rice called attention to the importance of uninterrupted service and to time tests on insulators. He predicted that the highest transmission voltage would very soon be generated directly by the dynamos, without the use of raising transformers. He also thought that the shoulder on the proposed pin was too small as the side strain would cause the shoulder to cut into the cross-arm, thus enlarging the hole so that the pin would finally pull out.

MR. SCOTT:—I recall my first experiments on the relation between the telephone and a high voltage. In the laboratory a telephone was connected in circuit between a high-tension terminal and a short length of wire. It gave a vigorous sound which was attributed to the flow of current to the wire acting as a condenser. The wire was disconnected and the telephone still responded. The wire was then disconnected from the telephone circuit and was connected to the insulated magnet. The telephone still responded.

Some measurements upon the potential generated on an insulated wire not far from a high tension circuit which were made by Mr. Tingley, who is here this evening, are reported in a paper on High-Voltage Transmission presented before the INSTITUTE by me in 1898. These experiments show that a single insulated wire not far from a high-tension wire may have a potential sufficient to cause a spark to jump over a considerable gap to the earth.

I had an opportunity a few years ago to inspect the burning of pins and cross-arms on a 10,000 volt transmission line on the Pacific Coast, which ran for some distance close to the shore. Large holes were burned in some of the cross-arms and poles. The burning was particularly apt to occur at the ends of the iron braces between the pole and the cross-arm. There was little doubt but that particles of sea water as "fog" were carried by the wind and deposited salt upon the poles and cross-arms. I understand that this difficulty has been avoided by placing wooden frames over the insulators on the ocean side.

Mr. I. Sternefeld of Mexico has called my attention to the deterioration of copper wire due to the salt air from the ocean. He says that he has found a satisfactory remedy in an insulated coating consisting simply of cotton dipped in a solution of minium and linseed oil.

It is notable that *megohms*, which used to be considered of prime importance in the testing of electrical apparatus, has not been mentioned in the discussion this evening. The problem in line construction is primarily to prevent disruptive and disastrous breakdown. It is not the *ohms* but the *volts* which are of first importance.

The collection of insulators before us this evening, containing some early forms as well as recent ones, small insulators as well as big ones, indicates the evolution which has taken place in insulator construction, both in materials and form during the last ten years.

The insulator problem, as presented in the discussion this evening, is at the present time primarily a mechanical problem. Electrically, it is partly one of materials and partly one of geometry. There is an intimate relation between geometry and voltage in insulator design. There is also the commercial problem.

High-tension tests upon apparatus, particularly transformers, is an important matter. The conditions prevailing at high voltages are to my mind different from those at lower voltages. Low-voltage apparatus may probably be tested at several times its operating pressure. The margin between the normal pressure and the test will be but a few thousand volts. If, however, transformers for 40,000 or 50,000 volts be tested at double pressure the margin is also 40,000 or 50,000 volts. The purpose of making a test of this kind is to determine first whether the design is satisfactory in giving sufficient surface distance and the like, and second to detect flaws in material or in construction. A momentary or short test is in general sufficient to determine these points. The prolonged test may have a deleterious effect upon the insulating materials by weakening them. The test may result in a break-down due to conditions entirely abnormal to service. On the other hand, although there may be no breakdown the materials may be left in a condition weaker than they would have been if the test had not been prolonged.

DISCUSSION AT MINNEAPOLIS, MINN., APRIL 3, 1903.

The Minnesota Branch held its 11th regular meeting Friday, April 3d, at the Electrical Building at the State University. Six members and 13 visitors attended.

The meeting was devoted to the four papers of the Transmission Committee. The papers were read, and produced considerable discussion. Prof. D. C. Jackson, of Wisconsin State University, and Dean F. S. Jones, of the Engineering Department of Minnesota State University, were present. The opinion of the members regarding the papers and new ideas brought forth were:

1st. That the proposed standardization of pins and pole construction must consider not only the transmission voltage, but particularly such local conditions as mist and dampness at inland lakes and from the ocean, of salt storms, the amount of lightning, etc.

2d. Regarding wooden pins, that trouble from same must be expected in time, say after fifteen years' service, when the pins have weakened mechanically. An iron pin would seem to be more permanent.

3d. That wooden pins should not have a shoulder just above the cross-arm. The use of a shoulder produces additional mechanical strains in the pin at the cross-arm or shoulder not considered in the formula or theoretical basis given by Mr. Merzhon. The shoulder was considered a relic from telephone lines and not necessary or advisable where there are heavy mechanical strains.

4th. That in service, the great majority of the insulator failures were mechanical and were due to strains produced by a poor fit between the pin and the insulator. Manufacturers of porcelain and glass insulators in the States produced excellent insulation, but the threads were not of uniform size in each and every insulator, as in those made by foreign manufacturers. The best workmanship is also desired in cutting the iron or wooden threads of the pin.

5th. That transmission lines as a whole—the pole, arm, pins, insulators and power circuits—have many weak links, in a long line. It is advisable where there are two or more companies, possibly competing for the power business of a city, to have connecting circuits and even to operate their lines in parallel. A somewhat similar arrangement is common among steam railways. A competing road gives the use of its tracks to a rival during temporary trouble to roadbed or at a burned-out bridge. A working arrangement of this nature, *i.e.*, to assist each other as far as possible in times of trouble, would help the reputation of power transmissions.

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Eclairage Electrique. Vol. 1-29. 4°. Paris. 1894-1901.

Edinburgh Philosophical Journal. 83 vols. 8°. Edinburgh. 1819-1860.

English Mechanic and World of Science. Vol. 1-22. Q. London. 1865-1876.

Fortschritte der Physik. 1845-1899. Vol. 1-55. 8°. Berlin. 1847-1900.

This set serves as a continuation of Gehler's "Physikalische Wörterbuch" (1825-1845), in the Wheeler Gift.

(La) Lumière Electrique. Vol. 31-34, 39-53. 4°. Paris. 1889, 1891-1894.

These volumes complete the set in the Wheeler Gift.

Memoirs of the Manchester Literary and Philosophical Society. Vol. 1-46. 8°. Manchester. 1789-1900.

Proceedings of the Manchester Literary and Philosophical Society. Vol. 1-26. 8°. Manchester. 1857-1887.

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These volumes complete the set in the Wheeler Gift with the exception of thirteen volumes.

BERLY, J. A. *Universal Electrical Directory.* 404 pp., 8°. London. 1887.

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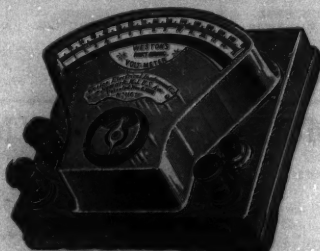
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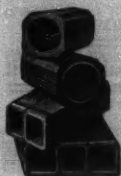
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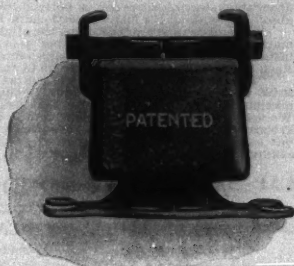
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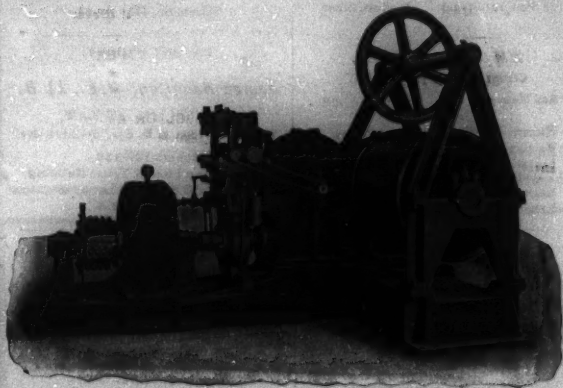
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In its Bulletin for December, 1902, the Edison Electric Illuminating Company of Brooklyn gives the following table. It shows the average monthly earnings of the company, for the past year, on 25 electric passenger elevators and 25 electric freight elevators.

Passenger Elevators			Freight Elevators			
No.	H.P.	Cost per Month		No.	H.P.	Cost per Month
1	7½	\$ 8.64	COST OF RUNNING PASSENGER ELEVATOR	1	5	\$ 5.52
1	7	17.98		1	7	4.32
1	8	21.59		2	20	22.93
1	7½	34.26		1	5	8.86
1	5	10.95		1	7½	2.88
1	7½	10.37		1	5	5.40
1	6	31.47		1	5	24.28
1	12	12.19		1	7½	7.89
1	7½	15.74		1	5	1.80
1	15	48.22		1	10	4.68
1	12	31.53	COST OF RUNNING FREIGHT ELEVATOR	1	7½	3.96
1	5	24.55		1	7½	4.32
1	7½	15.36		1	7½	32.26
1	6	7.24		1	5	5.72
1	6	5.64		1	7½	5.40
1	6	4.92		1	7½	2.40
1	5	14.50		2	20	25.85
1	15	22.94		1	7½	8.88
1	12	23.51		1	10	29.16
1	7½	5.16		1	4	9.29
1	10	8.32	Average cost per month per freight elevator.... \$10.21	1	7½	20.16
1	8	9.98		1	10	18.15
1	15	20.58		1	7½	6.27
1	10	4.80				
1	10	22.93	Average cost per month per H. P.....\$1.98			
25	218	\$433.37		25	186	\$255.36

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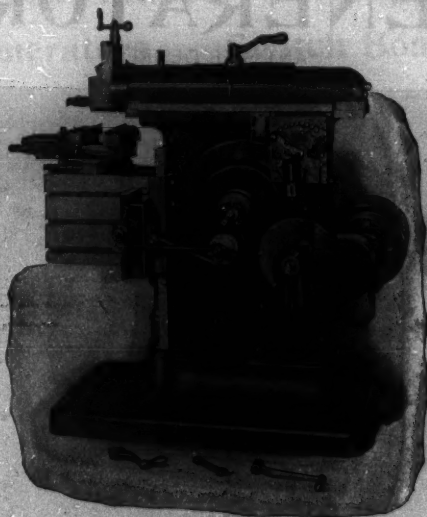
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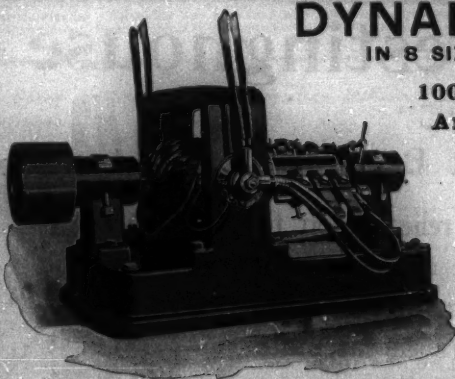
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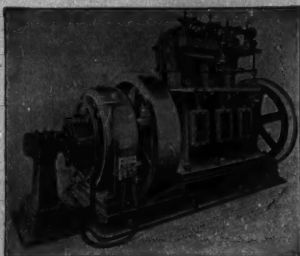
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APPLICATION FOR ADMISSION AS ASSOCIATE.

Extracts from the Constitution, as Amended May 21st, 1901.

MEMBERSHIP.

1. The corporate members of the Institute shall be designated as Members and Associates. Members and Associates shall be equally entitled to all of the rights and privileges of the Institute, except eligibility to the offices of President and Vice-President which shall be limited to Members; and Members only shall be entitled to a diploma. There shall also be Honorary Members, who shall be entitled to all the rights and privileges of the Institute, except the right to vote for officers and hold office.

2. A Member shall have been an Associate, and at the time of his transfer to membership, he shall be not less than twenty-seven years of age, and shall be:

- A Professional Electrical Engineer; or
- A Professor of Electrical Engineering; or
- A person who has done important original work of recognized value to electrical science.

3. To be eligible to membership as a professional Electrical Engineer, the applicant shall have been in the active practice of his profession for at least five years; he shall have had responsible charge of work for at least two years, and shall be qualified to design as well as direct electrical engineering works. Graduation from a School of Engineering of recognized standing shall be considered the equivalent of one year's active practice.

4. To be eligible to membership as Professor of Electrical Engineering, the applicant shall have been in responsible charge of a course of Electrical Engineering at a college or technical school of recognized standing, for a period of at least two years.

5. An Associate shall be a person who is interested in or connected with the study or application of electricity.

DUES.

1. The entrance fee, payable on admission to the Institute, shall be five (5) dollars. A fee of ten (10) dollars shall be paid on transfer to the grade of Member, which shall include the fee for a diploma.

2. The annual dues shall be fifteen (15) dollars for members and ten (10) dollars for Associates.

3. The annual dues of Members and Associates residing in foreign countries other than Canada and Mexico, shall be ten (10) and five dollars, (5) respectively.

4. Honorary Members shall be exempt from all payments.

5. Persons elected after six months of the fiscal year have expired, shall pay one-half of the amount of dues for that fiscal year.

6. A Member or Associate in good standing, by the single payment of two hundred (200) dollars in addition to his entrance fee, shall become exempt from all future payments for dues or transfer fee. All money thus paid shall be invested as a permanent fund, of which the interest only shall be subject to appropriation for current expenses.

To the Board of Directors of the American Institute of Electrical Engineers.

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and at present associated with

as

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Signature and
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publications and
communications
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Name of original proposer, through whom application is made.

These spaces to be filled in by applicant.

Article III, Sec. 2.—An application for admission to the Institute as Associate..... shall refer to at least three Members or Associates.

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cate with these
references.

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2. What education, general and technical, have you had; where and how acquired?
3. What is and has been your employment; how long have you been employed in each position referred to?

The undersigned certifies that the above statements are correct and agrees, if elected by the Institute, that he will be governed by the Constitution as long as his connection with it shall continue. He furthermore agrees to promote the objects of the Institute as far as shall be in his power, and in case of his serving his connection therewith that he will return his membership badge, if he has purchased one; provided that for the latter \$2.00 shall be refunded.

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Date, ... 190

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